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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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VOL. CVII.—No. 2787.] *LONDON: FRIDAY, MAY 30, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE...9d. BY INLAND POST ... 11d.

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See Illustrated Advertisement
Page 127, May 16.

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Always British Large Sizes.
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SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
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Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3531
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See page 17, May 23. 7263

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W. H. SPENCER & CO., HITCHIN, HERTS
See page 15, May 23. 7454

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London, S.W. 1.

"Aptol" Lubricants.
WORKS: SALFORD, MANCHESTER. 7184

Iron and Steel
Tubes and Fittings.
6920
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See Advertisement page 103.

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FEED WATER HEATERS,
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Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
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LIVERPOOL WAREHOUSE—63, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—132, BUTE ST.
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See Advertisement page 28. 7268

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are foremost as fire fighters. No Acids. No Alkalis. Safe to use and always ready.—BRITISH FIRE APPLIANCES Co., Ltd., 109, Victoria St., London, S.W. 1.

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ENGINEERING, IRON AND STEEL WORKS
Valuers.
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7168
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(ELECTRIC).
7182
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Duckham's Patent Suspended
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See Illus. Advt. last week, page 15. 7046

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See's Hydro-Pneumatic Ash Ejector.
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20/t. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

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EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
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Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

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6064
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See Advertisement page 86, May 9. 2402

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FOR MUNITIONS OF VICTORY,
SCRAP IRON, STEEL AND OTHER METALS.
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AMERICAN PULVERIZED COAL SYSTEMS.
Furnace Design (Melting and Heat Treatment).
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See half-page Advertisement page 108, May 16.

B. & S. Massey, Ltd., MANCHESTER.
Steam Hammers,
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Drop Stamps,
Band Saws. 7326
QUICK DELIVERY. LARGE STOCK.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

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Founded 1854 by SIR WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 7479

The Manchester Steam Users' ASSOCIATION.

The ANNUAL GENERAL MEETING of the Members was held in the Board Room of the Association, at their Offices, 9, Mount Street, Manchester, on Tuesday, May 27th, HAROLD LEE, Esq., J.P. (Manchester), President, in the Chair, when the following resolutions were adopted:—

Moved by the Chairman, seconded by FREEMAN B. T. TREVELYAN, Esq. (Openshaw), and resolved—

"That the Report of the Committee of Management to the Subscribers be adopted."

Moved by JAMES GARDINER, Esq. (Messrs. Richard Evans & Co., Ltd., Haydock), seconded by H. C. STONEHOUSE, Esq. (Messrs. Mathew P. Stonehouse, Wakefield), and resolved—

"That the thanks of the Association are due and are hereby presented to the Committee of Management for their past services, and that the following gentlemen be elected the Committee for the ensuing year, with power to add to their number."

COMMITTEE OF MANAGEMENT:

HAROLD LEE, Esq., J.P., Manchester.
CHARLES HEATON, Esq., Bolton.
EDWARD HOPKINSON, Esq., D.Sc., M.P., Manchester.
HENRY WHITEHEAD, Esq., M.V.O., Bury.
A. NORMAN DUGDALE, Esq., Blackburn.
FREEMAN B. T. TREVELYAN, Esq., Openshaw.
JAMES S. ADDISON, Esq., Manchester.

Moved by F. CLEGG, Esq. (Messrs. Turner Bros., Ltd., Rochdale), seconded by P. R. WILLCOCKS, Esq. (Messrs. Wilson Bros. Bobbin Co., Ltd., Garston, Liverpool), and resolved—

"That Messrs. F. W. POPPLEWELL & SON, Chartered Accountants, Manchester, be appointed Auditors of the Association's accounts for 1919.

EDWARD A. BATEMAN, Secretary.
9, Mount Street, Albert Square, Manchester.
May 28th 1919.

Association of Engineering AND SHIPBUILDING DRAUGHTSMEN.

CENTRAL LONDON SUB-BRANCH.

The QUARTERLY MEETING of Members will be held at the Central Hall (Committee Room B), Westminster, S.W. 1, on WEDNESDAY, JUNE 4TH, at 7.30 p.m. prompt.

It is very important that every Member should be present.

Particulars of membership, etc., can be obtained from the Recruiting Secretary for this Sub-Branch, Mr. A. KEY, 139, The Grove, Hammersmith, W. 6.

M. R. DEWHURST, W 195
Hon. Secretary.

Industrial Administration.

MR. EDWARD T. ELBOURNE,
AUTHOR OF
"FACTORY ADMINISTRATION AND ACCOUNTS,"

will give, during JUNE and JULY, at WINCHESTER HOUSE, OLD BROAD STREET, E.C., THREE COURSES of EIGHT LECTURES each in the following subjects:—

A.—FACTORY ORGANIZATION.
WEDNESDAYS, 6 p.m. Commencing JUNE 4.
Chairman for opening lecture:—
Major-General the Hon. Sir F. R. BINGHAM, K.C.M.G., C.B.

B.—LABOUR ADMINISTRATION.
THURSDAYS, 6 p.m. Commencing JUNE 5.
Chairman for opening lecture:—
J. A. SEDDON, Esq., C.H., M.P.

C.—FACTORY COSTING.
FRIDAYS, 6 p.m. Commencing JUNE 6.
Chairman for opening lecture:—
Sir JOHN E. THORNYCROFT, K.B.E., Managing Director, Messrs. John I. Thornycroft & Co., Ltd.

DISCUSSION WILL FOLLOW EACH LECTURE.

FEE.—ONE GUINEA FOR EACH COURSE.

Syllabus, on application by post, to—
MESSRS. BRINDLEY & ELBOURNE,
Consulting Engineers,
110, Victoria Street,
Westminster, S.W. 1.
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THE UNION OF SOUTH AFRICA.

SUPPLY OF LOCOMOTIVE BOILERS.

Tenders are Invited for the

SUPPLY and DELIVERY of 69 LOCOMOTIVE BOILERS, for the South African Railways. Drawings can be seen at Messrs. HODGES, BENNETT AND CO.'s Office, 16, Victoria Street, Westminster, S.W. 1, and copies may be obtained at usual charges.

Specifications and Conditions of Contract may be obtained (as ready) from the Stores and Shipping Department Office of the High Commissioner for the Union of South Africa, 32, Victoria Street, Westminster, S.W. 1.

Tenders marked outside "Tender for Locomotive Boilers," to be addressed to the SECRETARY, Office of the High Commissioner for the Union of South Africa, 32, Victoria Street, S.W. 1. They will be received up to Noon, on Monday, the 14th day of July, 1919.

The lowest or any Tender not necessarily accepted. W 55

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

MACHINERY AND PLANT AT THE R.E. EXPERIMENTAL STATION, WEMBLEY.

Tenders are Invited for

MACHINERY and PLANT, at R.E. Experimental Station, Wembley, including:—

Machine Tools: Lathes, 7 in. and 5½ in. centres; S.S. and S.C. Drilling Machines, Emery Grinders, Suction Gas Plant, Engines, &c., Electric Generators, Dynamos and Motors, ⅛ to 14 H.P., D.C. 200 to 300 volts.

Woodworking Machinery, Morticing and Boring Machine, Circular Saws, &c.

Tenders to close by June 7th.

Full particulars, together with permits to view and Tender Forms can be had on application to the CONTROLLER OF MACHINERY AND PLANT, Charing Cross, Embankment Buildings, W.C. 2. Telephone, Gerrard 540. W 139

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

THE MINISTRY OF MUNITIONS HAS

For Disposal,

124,323 DRAWN WELDLESS STEEL TUBES,
Length, 1 ft. 10 in.
External dia. 2 in.
Thickness of Steel ¼ in.
Average Weight 9½ lb. each.
One ¼ in. Hole, Drilled 1 in. from Open End.
One End Plugged.
In Good Condition.

Tender Forms can be obtained from
D.B. 4A, Room 382,
Hotel Metropole,
London, W.C. 2. W 85

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

THE MINISTRY OF MUNITIONS HAS

For Disposal,

299 AIR CYLINDERS FOR STROMBOS HORN,
In Good Condition.

Length, including Cap, 23½ in., external dia. 4½ in.
Steel Thickness 176 in. 28/35 tons Steel.
One Ordinary Brass Flat-seated Air Valve.
Fitted to each Cylinder, average weight 18 lb. each.

TENDERS ARE INVITED.

Tender Forms can be obtained from:—
D.B. 4A, Room 382,
Hotel Metropole, London, W.C. 2. W 87

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

THE MINISTRY OF MUNITIONS HAS

For Disposal,

TANK COMPONENTS,
202 Bullet-proof 6 m/m. Plates.
197 Bullet-proof 9 m/m. Plates.
272 Bullet-proof 12 m/m. Plates.
Rectangular of various dimensions.
89 SEMI-CIRCULAR GEAR COVERS 10 S.W.G., Mild Steel, 6 in. inside clearance, 10 S.W. Gauge.
85 PAIRS R. & L. HANDED GEAR COVER PLATES, Semi-circular Shape, Mild Steel, about 12 in. radius, 10 S.W.G.
168 EXHAUST PIPES,
8 ft. 5 in. long by 1½ in. internal diameter by ⅛ in. thick.
20 SUPPORT BRACKET FORGINGS,
6½ in. by 6 in. by 5 in.
SIX TOWING SHACKLE EYES,
9 in. dia., with Eye Lug.
62 RADIATOR MILD STEEL FANS,
17 in. dia.
Built on Cast Iron Boss for 1½ in. Shaft.
24 C.I. RADIATOR FAN BRACKETS,
20 in. dia.
25 MACHINED MILD STEEL COVERS,
10 in. dia.

TENDERS ARE INVITED.

Material can be viewed at C.S.D. DEPOT, GREAT CENTRAL YARD, LEICESTER.

Tender Forms can be obtained from:—
D.B. 4 A., Room 382, W 86
Hotel Metropole,
London, W.C. 2.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD MINISTRY OF MUNITIONS.

The Minister of Munitions has

For Disposal, 113,800 Pieces

of CHAINMAIL, average over all size of pieces 9 in. by 2½ in.
Average weight of pieces 4½ ozs. each.
Mesh made from No. 19 S.W.G. Steel Wire.
Over all size of rings ¼ in. diam.
Samples can be seen at Room 380, Hotel Metropole.
TENDERS ARE INVITED.
Tender Forms can be obtained from D.B.4A., Room 382, Hotel Metropole, London, W.C. W 126

DISTRICT ASYLUM, BALLINASLOE.

RENEWAL OF ELECTRIC ACCUMULATORS.

The Joint Committee of Management of above Asylum will, at their Meeting to be held on MONDAY, 9TH day of JUNE, 1919, open and consider

Tenders for the Renewal of

ELECTRIC ACCUMULATOR PLANT, as per specification to be had on application to the Resident Medical Superintendent, from whom any further information may be obtained.

The Accumulator plant consists of 108 cells (15 plates to each cell) and has a normal charge rate of 35 amperes.

Sealed Tenders marked "Accumulators," addressed to the RESIDENT MEDICAL SUPERINTENDENT, to be delivered at this Asylum on or before Twelve o'clock noon, on SATURDAY, the 7TH day of JUNE, 1919.

The lowest or any Tender not necessarily accepted.

By Order of the Committee.
JOHN MILLS,
Resident Medical Superintendent.
12th May, 1919. W 92

ESTIMATES ON
PUMPING PLANTS, TRANSFORMERS,
RE-FORMERS, &c.

For Account of the City

WATER WORKS, of Stockholm (Sweden), the following estimates are asked for:—

A high-pressure PUMPING PLANT, capacity 600 litres per second, with direct-coupled steam turbine.

A high-pressure PUMPING PLANT, capacity 600 litres per second, with direct-coupled electric motor.

A filter PUMPING PLANT, capacity 400 litres per second, with direct-coupled electric motor.

A speedy firing STRAM BOILER.

A TRANSFORMER PLANT.

A RE-FORMER.

ELECTRIC WIRES, conduits for water and steam, &c.

Estimates to be furnished at the
OFFICE OF
STOCKHOLMS VATTENLEDNINGSVERK,
Torsgatan 30, Stockholm,
on TUESDAY, 1st JULY, 1919, at 2 p.m. at the latest.

Particulars necessary for delivering estimates will be given at the address aforesaid, where necessary drawings, programmes, and formula for contracts, also are handed out, against the deposit Sw. Krs. 25, which sum will be refunded on delivery of estimate and restitution of documents in a sound condition.

W 164

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

OLD MATERIALS FOR SALE.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Purchase of

OLD MATERIALS.

Forms of Tender, giving full particulars, can be obtained on application to the STOREKEEPER, General Stores Department, Broadstone Station, Dublin.

Tenders must be posted in time to be received at Broadstone, on Tuesday, 10th June, 1919.

By Order,
Broadstone Station, PERCY A. HAY,
24th May, 1919. Secretary. W 103

TO BUILDERS MERCHANTS, ROOFING CONTRACTORS AND OTHERS.

re BRITISH CORRUGATIONS, LTD.
(IN LIQUIDATION).

Tenders are Invited for the

PURCHASE of the WHOLE of the Stock of ASBESTOS CORRUGATED SHEETING at present stored at the Company's Works, Northfleet, Kent. The Sheeting is of standard width of approximately 27½ inches, and is in lengths varying from 1½ feet to 10 feet.

The Stock can be inspected at the Works at any time by permit issued by me, but no guarantee or warranty whatever is to be implied or given by me in regard to the Stock.

Tenders should be for the whole of the Stock of the Corrugated Asbestos Sheeting as it now stands. The removal of the same will be at the risk of the Purchaser, who will also bear the cost of the removal, and pay for the Stock in cash prior thereto.

A quantity of Asbestos Fibre in bags is also in Stock for which the Liquidator is prepared to receive Tenders on the above terms.

All Tenders received by me at my address as below before Nine a.m. on Tuesday, 10th June, 1919, will be considered, but I reserve the right to refuse the highest or any Tender.

H. H. BARHAM, F.C.A.,
Liquidator,
British Corrugations, Ltd., W 100
College Hill Chambers,
23nd May, 1919. London, E.C. 4.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD MINISTRY OF MUNITIONS.

2540 PLUMMET CHAINS FOR SALE BY TENDER

Tenders (Ref. D.13) Addressed

to the CONTROLLER, D.B 5A., 37/41, Old Queen Street, Westminster, S.W. 1., will be received up to Noon, on MONDAY, 16th JUNE, 1919, for:—approximately 2540 PLUMMET CHAINS, lying at MESSRS. WILLMY & CO., ENGINEERS, EXETER.

Tenders to be endorsed "Tender for Plummet Chains," and reference number quoted in all cases.

Tender Forms, Schedules and particulars can be obtained from Controller, at the above address. W 221

G. R.

BY DIRECTION OF THE DISPOSAL BOARD. MINISTRY OF MUNITIONS.

MANILLA TOWING SPRINGS FOR SALE BY TENDER.

Tenders (Ref. D.15) Addressed

to the CONTROLLER, D.B 5A, 37/41, Old Queen Street, Westminster, S.W. 1, will be received up to Noon on MONDAY, JUNE 16TH, 1919, for 986 Lengths 7 in. MANILLA TOWING SPRINGS. (10 fathoms lengths) complete with eye and ring. Lying at I.W.D. DEPOT, RICHBOROUGH.

Tenders to be endorsed "Tender for 7 in. Manilla Towing Springs" and reference number quoted.

Tender Forms, Schedules and particulars can be obtained from the CONTROLLER at the above address. W 222

JHARIA WATER SUPPLY SCHEME.

Tenders are Invited for the

supply and delivery of WATER PIPES (Cast Iron, Steel or Reinforced Concrete) up to 21 in. internal diameter, together with Sluice Stop Valves, &c., to be used in conjunction with the pipes. If of cast iron, the total weight of pipes will be about 15,000 tons. The total length of pipes of all sizes will be about 102 miles. Sealed tender, accompanied by a depcait of £300 sterling (or equivalent sum, which will be returned to unsuccessful tenderers as soon as possible after the contract is let) will be received at the office of Messrs. SIR ALEXANDER BINNIE, SON & DEACON, 30, Buckingham Gate, Westminster, S.W. 1, up to mid-day on the 31st July, 1919.

Copies of the Form of Tender, Contract Agreement, Specification and Bills of Quantities may be obtained by sending in an application with a deposit of £6 sterling (or equivalent sum) for each copy applied for to Messrs. SIR ALEXANDER BINNIE, SON & DEACON, 30, Buckingham Gate, Westminster, S.W. 1, and such deposit will be refunded when a *bona fide* tender accompanied by the Specification, &c., has been received by the Chairman of the Jharia Water Board. The Board does not bind itself to accept the lowest or any tender.

(Signed) T. LUBY,
Chairman of the Jharia Water Board,
Dhanbad, B.I.R. W 236

APPOINTMENTS OPEN.

UNIVERSITY COLLEGE, NOTTINGHAM.

DEPARTMENT OF ENGINEERING.

LECTURER IN MECHANICAL ENGINEERING.

Applications are Invited for

the POST of LECTURER in Mechanical Engineering, at a commencing salary of £250 per annum.

Particulars and forms of application, which should be returned not later than June 18th, may be obtained from

J. E. SHIMELD, W 186
Acting Registrar.

GLAMORGAN EDUCATION COMMITTEE.

APPOINTMENT OF LECTURERS IN MECHANICAL ENGINEERING.

The Committee propose to

Appoint Two Additional

LECTURERS in Mechanical Engineering. Applicants must possess special qualifications for teaching Mechanical Engineering and allied subjects. Successful candidates must devote their whole time to the duties and reside where directed by the Committee.

Salaries £350 per annum, rising by annual increments of £10 to a maximum of £350, with expenses according to scale. Regard will be had to previous experience in assessing the commencing salary. Canvassing will disqualify.

Applications, on forms which will be supplied on receipt of a stamped addressed foolscap envelope, accompanied by copies of not more than three recent testimonials, must reach the CHIEF EDUCATION OFFICIAL, County Hall, Cardiff, by 14th June, 1919. W 145

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE.
(COLEG PRIFATHROFAOL DEHEUDIR CYMRU A MYNWY.)

The Council of the College invites

Applications for the following

POSTS. Applications, with testimonials (which need not be printed), must be received by the undersigned on or before the date stated in brackets after the title of each post.

(1) Assistant Lecturer and Demonstrator in Engineering. (June 14, 1919.)

(2) Assistant Lecturer and Demonstrator in Metallurgy. (June 30, 1919.)

Further particulars regarding the above posts may be obtained from the undersigned.

D. J. A. BROWN,
Registrar.

University College,
Cardiff.
May 17th, 1919. U 985

A Large Firm of Engineers

in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4336, Offices of ENGINEERING.

THE ATLANTIC FLIGHT.

By G. GREENHILL.

THIS daring project is engaging such universal attention, and inspired prophecy is so constantly at work giving figures of the performance anticipated, that it is permissible to return again to the considerations propounded in February last (page 161 *ante*) and to submit the figures and calculations to the cold test of arithmetic. The airships (L/A, lighter than air), constructed already, have the size and endurance required for a voyage of 3,000 miles and over, without descending for a fresh supply of motor fuel, and are only waiting for moderate weather to make a start. Their performance appears to-day so humdrum compared with the difficulties of the flying machine (H/A, heavier than air) as to attract little attention by comparison. Moreover, they are ineligible for *The Daily Mail* prize of 10,000*l.*, and so cannot participate in the sporting interest of a racing competition.

The only airship difficulty to be anticipated is on departure, or again on arrival, supposing the weather should take an unfavourable turn at the end of the voyage; from no trouble of draught, and depth of water over the bar, or waiting for a tide; but of housing or mooring the airship, at start and finish. So we confine our attention here for the present to the H/A flying machine, with no sustentation power or lift, except when running at full speed.

Flying over the sea, not high up, but in air of nearly normal ground density, we assume the experimental law that a 12-knot wind will give a pressure of 1 lb per square foot (lb/ft²) when the incidence is normal; and then, on the simple sine law, the lift at K knots on A ft² of wing, at a slope of 1 in n with the course of flight, will be $\frac{A}{n}\left(\frac{K}{12}\right)^2$ lb; here is contained all the physical assumption required for building up the subsequent theory; "Les principes des mathématiques sont enoncés dans les definitions" (Pascal).

Flying horizontally, the lift must support the weight, W lb; while the thrust required to overcome the drag or drift will be $\frac{W}{n}$ lb; and so the thrust horse-power is here $\frac{W\,K}{330\,n}$, taking the usual estimate of 1 h.p. at 330 knot-lb.

But head resistance is too important to be left out of account; if this is estimated as the equivalent of a vertical plane of B ft², driven against the air, the total thrust required of the screws is:

$$T = \frac{W}{n} + B\left(\frac{K}{12}\right)^2 = \frac{W^2}{A}\left(\frac{12}{K}\right)^2 + B\left(\frac{K}{12}\right)^2, \text{ lb};$$

and writing this, in a new algebraical arrangement,

$$T = 2W\sqrt{\frac{B}{A}} + \left(\frac{W}{\sqrt{A}}\cdot\frac{12}{K} - \sqrt{B}\cdot\frac{K}{12}\right)^2,$$

we see that T has the minimum value, $2W\sqrt{\frac{B}{A}}$, by making

$$\frac{W}{\sqrt{A}}\cdot\frac{12}{K} = \sqrt{B}\cdot\frac{K}{12},$$

and then

$$\left(\frac{K}{12}\right)^2 = \frac{W}{\sqrt{(A\,B)}}, \text{ or } n = \frac{A}{W}\left(\frac{K}{12}\right)^2 = \cdot\sqrt{\frac{A}{B}},$$

which decides, either the economical speed K, or else the most favourable n, for given A and B.

Supposing, then, the flight is carried out on these economical conditions, the

$$\text{thrust H.P.} = 2W\sqrt{\frac{B}{A}}\cdot\frac{K}{330} = 2\frac{W}{n}\cdot\frac{K}{330}$$

$$= 2\frac{W^2}{A}\left(\frac{12}{K}\right)^2\frac{K}{330} = 2\frac{W^2}{A}\cdot\frac{144}{330\,K},$$

varying inversely as K, or directly as W^2.

At an estimate of p lb of petrol per horse-power hour (whether indicated or thrust horse-power must be inferred from the figures supplied), the petrol for L miles or $\frac{L}{K}$ hours, is:

$$\frac{p\,L}{K}\times\frac{2\,W^2\times 144}{330\,A\,K} = \frac{2\,p\,L\,W^2}{330\,A}\left(\frac{12}{K}\right)^2$$

that is, at a rate of:

$$\frac{2\,p\,W^2}{330\,A}\left(\frac{12}{K}\right)^2, \text{ lb/mile; or } \frac{330\,A}{2\,p\,W^2}\left(\frac{K}{12}\right)^2, \text{ miles/lb.}$$

As we are dealing with a flight over the ocean, the sailor units of the geographical sea mile for length, and the knot for speed are the only ones suitable. Confusion in navigation is intolerable with the introduction of short measure in the land mile of the soldier. Then there is the French mile, shorter still, of the kilometre; this, however, is of cosmopolitan acceptation, and is convertible immediately into the sailor's mile by the factor 0·54, the distance from equator to pole being 90 × 60 = 5,400 sea miles, or 100 × 100 = 10,000 km.

But if the artillery unit of velocity is selected, of one foot per second, the standard 12 knots must be replaced by 20 f/s, and other velocity in proportion; and the power factor of 330 knot-pounds becomes 550 ft-lb/second, for H. P.

A tendency is discernible in commercial arithmetic to an attempt at a degradation of the standards, by always choosing the smaller unit, so as to make the numbers bulk larger. Thus the American short ton, of 2,000 lb, is creeping in as quietly as possible, and edging out the English long ton, of 2,240 lb.

During the flight it will not be possible to make any alteration in A and B; these have been settled beforehand in the design and manufacture; but n can be altered by the control. But if the flight is to be made economically, for the petrol to last as long as possible, n will be the constant $\sqrt{(A:B)}$; and the speed K at weight W will be given by

$$\left(\frac{K}{12}\right)^2 = \frac{W}{A}n = w\,n, \quad K = 12\sqrt{(w\,n)},$$

where $w = W/A$, the wing loading in lb/ft².
Thus with $w = 6$, $n = 6$, K = 72 knots;
$w = 10$, $n = 10$, K = 120 knots.

When account is taken of the loss of weight P as the petrol is consumed, the speed K′ must be varied as the square root of the remaining weight W − P, from the relation

$$\left(\frac{K}{12}\right)^2 = \frac{W-P}{A}n = w'n$$

w' denoting the reduced wing loading, in lb/ft.² Then if the flight is x miles after t hours, and P lb of petrol has been consumed, the miles/lb of petrol is there:

$$\frac{dx}{dP} = \frac{330\,A}{2\,p\,(W-P)^2}\left(\frac{K'}{12}\right)^2 = \frac{330\,n}{2\,p\,(W-P)}$$

and integrating,

$$x = \frac{330\,n}{2\,p}\log_e\frac{W}{W-P},$$

contrasted with the run y where the loss of weight P is not considered, as if the petrol was supplied as fast as consumed, when:

$$\frac{dy}{dP} = \frac{330\,n}{2\,p\,W}, \quad \therefore y = \frac{330\,n\,P}{2\,p\,W}, \quad \frac{x}{y} = \frac{W}{P}\log_e\frac{W}{W-P},$$

Thus, with

$$P = \frac{1}{3}W, \quad \frac{x}{y} = 3\log_e 1{\cdot}5 = 1{\cdot}2$$

an increase of 20 per cent in flight; or if, as stated for the Handley Page machine,

$$P = \frac{1}{2}W, \quad \frac{x}{y} = 2\log_2 2 = \cdot 38,$$

38 per cent increase; something like Mr. Glauert's figures.

The factor of increase W : W − P of the flight, given previously (February 7), was obtained by supposing the speed kept constant, and n to be varied to maintain the lift, to

$$n' = \frac{A}{W-P}\left(\frac{K}{12}\right)^2 = \frac{n\,W}{W-P}$$

also taking the petrol, in lb/mile, to vary as the square of the weight, $(W-P)^2$. Then the miles/lb vary inversely as $(W-P)^2$, and, by integration, the flight for P lb varies as

$$\frac{1}{W-P} - \frac{1}{W} = \frac{P}{W\,(W-P)},$$

instead of as $\frac{P}{W^2}$ when the weight is kept constant at W; thus the flight is stretched from W − P to W-fold. But this is equivalent to ignoring head resistance, and gives an estimate too favourable.

So, restoring the head resistance of B, and keeping the speed K constant by a variation of

$$n \text{ to } n' = \frac{n\,W}{W-P},$$

the head resistance,

$$B\left(\frac{K}{12}\right)^2 = \frac{A}{n^2}\left(\frac{K}{12}\right)^2 = \frac{W}{n},$$

is constant, but the thrust T is variable:

$$T = \frac{W-P}{n'} + B\left(\frac{K}{12}\right)^2 = \frac{(W-P)^2}{n\,W} + \frac{W}{n},$$

and after x' miles, the petrol consumption, in lb/mile:

$$\frac{dP}{dx'} = \frac{T\,p}{330}, \quad \frac{dx'}{dP} = \frac{330\,n}{p}\frac{W}{(W-P)^2 + W^2};$$

and integrating:

$$x' = \frac{330\,n}{p}\tan^{-1}\frac{P}{2W-P},$$

while

$$x = \frac{330\,n}{2\,p}\log_e\frac{W}{W-P}, \quad \frac{x'}{x} = \frac{2\tan^{-1}\dfrac{P}{2W-P}}{\log_e\dfrac{W}{W-P}},$$

which should always be less than 1, so long as W − P is positive. Negative W − P would imply a change from H/A to L/A.

Tested at:

$$W = 2P, \quad \frac{x'}{x} = \frac{2\tan^{-1}\frac{1}{3}}{\log_e 2} = \frac{0{\cdot}643}{0{\cdot}693} = 0{\cdot}93;$$

and

$$W = 3P, \quad \frac{x'}{x} = \frac{2\tan^{-1}\frac{1}{5}}{\log_e 1{\cdot}5} = \frac{0{\cdot}394}{0{\cdot}405} = 0{\cdot}97.$$

Flying at a height above sea-level at which the air tenuity factor τ of gunnery comes into account, the standard velocity we have taken of 12 knots must be divided by $\sqrt{\tau}$ to obtain the new standard velocity, $12 \div \sqrt{\tau}$ knot required in the attenuated stratum to give on normal incidence a pressure of 1 lb/ft².

Thus, for instance, at a height of 1 sea mile, 1,000 fathom, say 6,000 ft, and taking the air density reduced by 20 per cent, on the old rule of an inch fall in the barometer for 1,000 ft of ascent, a drop from 30 in. to 24 in.; then the speed must be increased 10 per cent, or be raised from 12 knots to 13·2 knots to give the normal pressure of 1 lb/ft². And at a height where air density is halved, 12 will require to be raised to $12\sqrt{2} = 17$ knots, and the other velocity in proportion.

Here is a rough practical application which will serve for the purpose of the Atlantic flight; because a height record is not contemplated, such as a ceiling of 20,000 ft to 30,000 ft, in which case elaborate meteorological formulas would be required, and a careful statement of the temperature encountered. Flying high or low, the petrol lasts the same distance; but the high flight has the advantage of the extra speed, increased inversely as the square root of τ.

Coming now to actual figures, we select the Handley Page machine as the one condescending to divulge the most detailed information.

We are given a weight W = 28,000 lb (say 12·5 tons, in long English tons, not the American short ton of 2,000 lb); and 1,400 h.p. from four engines, each of 350 h.p. But it is not stated if this is discounted thrust horse-power, or gross indicated horse-power, determined by trial with a break dynamometer; these may differ by 50 per cent and over.

But conceding every advantage, and assuming 1,400 as the net thrust horse-power delivered by the screws, and accepting the statement that the petrol carried 2,000 gallons, say 14,000 lb, will last for a flight of 2,500 miles, that is for 25 hours at 100 knots, we read a claim of petrol consumption at the rate of 0·4 lb/H.P.-hour, whereas it is prudent to double this figure, or to reckon an allowance of more like a pint or 1 lb, or even ½ kg/H.P.-hour, lubrication included; and at 100 knots the petrol supply of 2,000 gallons must not be expected to last more than 10 hours, a flight of 1,000 miles. At this rate the Handley Page machine would be compelled to descend once at least on the voyage, reckoned at over 2,000 miles, to replenish the petrol.

And so on for the other machines, where any figures are divulged which can be subjected to the test of arithmetical calculation.

It seems prudent to reckon the passage at 2,400 miles through the air, and to assign a diameter of action of the H/A flying machine of not more than 800 miles, thus requiring a descent to the water twice over; and special tender steamers, of the destroyer type, should be in waiting at the intervals, or even at every 200 miles, ready with a fresh supply of petrol. It is too early to consider whether

the petrol could be picked up by swooping down in flight, like the letter bags by a mail train.

It may be urged that 2,400 miles is an excessive estimate, and that the passage could be reduced to 1,800 miles, from Newfoundland to Ireland, or Iceland; but this involves a route far away from the lanes of ordinary steamship traffic; and these should be followed closely, at least in the initial experimental flights, to be able to take advantage of rescue at hand in case of accident and a forced descent.

The airship may be trusted to choose any great circle course round the world; and then the nearest way to China and Japan would be over the top, close to the North Pole. And the South Pole would be passed not very far off in the great circle from Cape Town to Adelaide or Melbourne.

The old problems arise here, again, but in a more remarkable way, of the apparent length of the day in the westward and eastward passage, and of the number of steamers to be met and passed, and overtaken. Steamers of a daily line meet and pass every 12 hours, although starting 24 hours apart; but one never overtakes another. But here we are dealing with a speed in the air five or six times more than the speed on the water; like the omnibus line in the road and the pedestrians on the pavement.

A flying machine going at 100 knots along the steamship lane taken by a line of daily steamers making 360 miles a day, will meet a steamer and pass it with relative speed of 115 knots, and overtake another at 85 knots; so that the 360 mile interval will take $360 \div 115$ chronometer hours, a little over 3 hours for a meeting steamer; or $360 \div 85$ chronometer hours, a little over 4 hours to overhaul another steamer the other way. The Sun may be considered a daily steamer, with a run on the equator of 21,600 miles at 900 knots, or 900 cos. lat. knots along a parallel of latitude, and here it is the Sun overtakes the flying machine on the westward passage, and meets it on the return passage.

Take the case of a westward flight at K knots over a distance of D miles to a place H hours west in longitude. The chronometer hours of the voyage are D/K, but the apparent time on arrival is D/K − H hours; and so a speed is claimed of:

$$\frac{D}{D/K - H} = K + \frac{H K^2}{D - H K},$$

an apparent gain in speed through the water of $H K^2/(D - H K)$ knots.

For instance, if D = 2,400 miles, and H = 4 hours, the apparent gain of speed over 100 knots is 20 knots, raising the legend speed to 120.

The return journey to the eastward is preferred, on account of the favourable current of air presumed. Here the speed would appear to have diminished by $H K^2/(D + H K)$; or over 14 knots; but this depreciatory result would be suppressed in a record.

An airship going west on a parallel of latitude would keep up with the sun at a speed of 900 cos. lat. knots, and this would be possible in high latitudes, say over 84 deg.

At a less speed of K knots, the time between noon on successive days will be $24 \div \left(1 - \frac{K}{900 \cos. lat.}\right)$ chronometer hours, and the day's run in the time will be $24\ K \div \left(1 - \frac{K}{900 \cos. lat.}\right)$ miles, a change of longitude of $24\ K \div (900 \cos. lat. - K)$ hours.

Thus at K = 100, 900 cos lat. = 600, the day is 28 hours 48 minutes long, the day's run is 2,880 miles, and the change of longitude is 4 hours 48 minutes, and a claim is made of a speed of 120 knots.

Similarly for the return on the eastern passage, results never mentioned, as unfavourable in describing a record.

Continuing this voyage westward round the parallel of latitude of 14,400 miles, the circuit will be completed in 144 chronometer hours, but in 120 hours or 5 days of sun time, and a day will have been gained.

The other way round to the eastward, a day will be lost, and the circuit will take 7 days.

In Jules Verne's play "Le tour du monde en quatre-vingt jours" ("Round the world in 80 days"), the route is by the Suez Canal, India, Borneo, San Francisco, and so by the eastward passage; and the 80 times it struck noon to the travellers would be heard only 79 times by the stakeholder in London, as required in the *dénouement*.

Any theoretical calculation of the height ascended from an observation of the barometer requires a reading of the thermometer as well. It is usually assumed, as a result of aeronautical experience, that the thermometer falls on a uniform gradient with the height ascended, expressed in the formula:

$$\theta = \theta_0\left(1 - \frac{z}{c}\right),$$

connecting θ the absolute temperature at a height z, with θ_0 the absolute temperature on the ground; this is a gradient of 1 deg. C drop for every c/θ_0 ft of ascent.

I have shown in my "Hydrostatics," that on this the hypothesis of the "Convective Equilibrium of the Atmosphere," the pressure p and density ρ equations are:

$$\frac{p}{p_0} = \left(1 - \frac{z}{c}\right)^{\frac{c}{k}}, \quad \frac{\rho}{\rho_0} = \left(1 - \frac{z}{c}\right)^{\frac{c}{k} - 1} = \left(\frac{p}{p_0}\right)^{1 - \frac{k}{c}}$$

where k denotes the height of the homogeneous atmosphere at the ground temperature θ_0; and this agrees with the usual adiabatic equation between pressure and density when we put

$$1 - \frac{k}{c} = \frac{1}{\gamma}, \quad \frac{c}{k} = \frac{\gamma}{\gamma - 1}.$$

In the official figures, the standard ground temperature is taken at 10 deg. C, or 50 deg. F, $\theta_0 = 283$, and $k = 27{,}000$ ft; but with change of temperature, k rises and falls like an air thermometer. And c is taken at $6\ k = 162{,}000$ ft, so that the temperature gradient is 1 deg. C down per $162{,}000 \div 283 = 573$ ft up. This is equivalent to taking $\gamma = 1{\cdot}2$, midway between $\gamma = 1{\cdot}4$ for real adiabatic expansion of air, and $\gamma = 1$, $c = \infty$, which would correspond to the Isothermal Atmosphere, at uniform temperature. And so we have unravelled the secrets of the official formula.

For example, at a height z where the density is halved, the official formula would give:

$$1 - \frac{z}{c} = \left(\frac{\rho}{\rho_0}\right)^{\frac{k}{c - k}} = \left(\frac{1}{2}\right)^{1} = 0.87,$$

$$z = 0.13 \times 162{,}000 = 21{,}000 \text{ ft},$$

with a fall of temperature $0{\cdot}13 \times 283 = 36{\cdot}8$ deg. C, to $246{\cdot}2$ deg. absolute, or $-\ 26{\cdot}8$ deg. C.

The barometric formula of Laplace is based on an Isothermal Atmosphere, at the mean temperature here about 265 deg. absolute; and it makes:

$$z = k \log_e \frac{\rho_0}{\rho} = 27{,}000 \times \frac{265}{283} \log_e 2 = 17{,}500 \text{ ft}.$$

The thermometer gradient is influenced by the relative temperature of the sea and the air above, in motion as wind. Thus if we took $c = k$, the air density ρ would be constant, and the pressure gradient would be the same as that of the thermometer, at 1 deg. C per $95{\cdot}5$ ft of ascent. At a steeper gradient the density would increase in ascending.

The influence of variable air density on the refractive index μ would be important in aerial navigation on the dip of the horizon. It is usual to assume that $\mu^2 - 1$ varies as the density, and that the effect is to bend a horizontal ray of light to a curve which may be assumed circular, and curved to 1 minute per n miles, against a curvature of 1 minute per mile for the surface of the sea; and then the distance of the visible horizon will have to be multiplied, or the dip will have to be divided, by $\sqrt{\left(\frac{n}{n-1}\right)}$, as if the Earth was magnified $\frac{n}{n-1}$ fold by the refraction of the air lens of the atmosphere. And the Earth will appear larger as we ascend, and not smaller according to ancient legend; and the surface will not look convex, but saucer shaped, like the bottom of the sea seen from a height above.

Assuming the air strata horizontal, $\mu \cos \theta$ is constant along a ray with a variable slope θ; and differentiating with respect to z:

$$\frac{d\mu}{dz} \cos\theta - \mu \sin\theta \frac{d\theta}{dz} = 0,$$

$$\frac{d\mu}{dz} = \mu \tan\theta \frac{d\theta}{dz} = \frac{\mu}{\cos\theta} \frac{d\theta}{ds} = -\frac{1}{n\,R},$$

when we put $\cos\theta = 1$, $\mu = 1$, for a ray nearly horizontal, curved to a radius n R, n times R the radius of the Earth.

According to Heath's "Optics," Chapter xiii, it is found by experiments of Biot and Arago that

$$\mu^2 - 1 = 4\lambda\,(\rho/\rho_0), \text{ with } 4\lambda = 0.0005888768.$$

Then, in the Convective Equilibrium:

$$\mu^2 = 1 + 4\lambda\left(1 - \frac{z}{c}\right)^{\frac{c}{k} - 1},$$

$$\mu \frac{d\mu}{dz} = -2\lambda\left(\frac{1}{k} - \frac{1}{c}\right)\left(1 - \frac{z}{c}\right)^{\frac{c}{k} - 2};$$

so that near the ground where

$$z = 0,\ \mu = 1,\ \frac{d\mu}{dz} = -2\lambda\left(\frac{1}{k} - \frac{1}{c}\right) = -\frac{1}{n\,R},$$

$$\frac{1}{n} = 2\lambda\,\frac{R}{k}\left(1 - \frac{k}{c}\right),$$

in which we may take

$$R = 800\ k, \text{ and then } \frac{1}{n} = 0.236\left(1 - \frac{k}{c}\right).$$

In an Isothermal state,

$$c = \infty,\ \frac{1}{n} = 0{\cdot}236,\ n = 4{\cdot}25.$$

In the official Convective Equilibrium,

$$c = 6\ k,\ n = 5.1.$$

For $n = 1$, c must be negative, and the temperature increase upward; so changing the sign of c,

$$1 + \frac{k}{c} = 4{\cdot}25,\ c = \frac{k}{3{\cdot}25} = 8{,}308 \text{ ft},$$

and the temperature gradient is a rise of 1 deg. F for every $\frac{c}{460 + 50 = 510} = 16{\cdot}3$ ft ascent; dip would be zero, and the horizon recede to infinity.

For a steeper temperature gradient, as over a frozen sea in the Arctic circle, objects on the horizon may be seen reflected in the sky, in a mirage; and it would be possible to see over land intervening in such an abnormal state of the air as is reported by gunners at Southsea, sighting over the Isle of Wight on shipping out at sea beyond.

At a height of 1 sea mile the visible horizon on a clear day would be given as 82 sea miles, increased by refraction about 12 per cent, with $n = 5$, say to 92 miles; to this must be added the miles of the horizon of a light-house, in estimating the distance on picking up the light, say an hour's run.

The rapid disappearance of a high light, such as the Fastnet, would be very remarkable, appearing to drop into the sea with acceleration K^2/R (knots an hour), R denoting the radius of the Earth in sea miles, $2\ \pi\ R = 21{,}600$; and with velocity K sin dip knots. Or the acceleration may be given as $g\ K^2/G^2$, where G is the velocity of a grazing satellite $G^2 = g\,R$; and $G = 17 \times 900$ knots. These appearances would be reversed in approaching the other way.

The new navigation required in an aerial voyage will require an additional chapter to itself in Lecky's "Wrinkles," to deal with these abnormal values of refraction, dip, horizon, speed, and change of longitude. Instructions have been issued for signalling latitude and longitude by wireless, but a schoolmaster seems to have had a hand in them, because longitude, as well as latitude, is to be signalled in degrees and minutes. This is to save confusion, the schoolmaster urges, who is thinking in his class-room; but nothing to the confusion, the sailor will say, if these figures are to be heard in the roaring of a gale, and a mistake is made between latitude and longitude, as formerly between larboard and starboard; impossible to happen if longitude is given, as always at sea, in hours and minutes of the chronometer. And the French authority is working hard to complete the logic of his metric system by introducing centesimal time on his chronometer, as in the "Mécanique céleste" of Laplace, to the confusion of the reader; again distending the figures of the record.

The competition for the prize of the Atlantic flight (*la coupe de l'Atlantique*) should be carried out on the courteous rules of sport, and the instructions for the destroyer tenders should be to attend to the needs of the first comer. We are not concerned with a game of cricket, where the object is to get the other side out

THE MOTOR SHIP "SANTA MARGHERITA."

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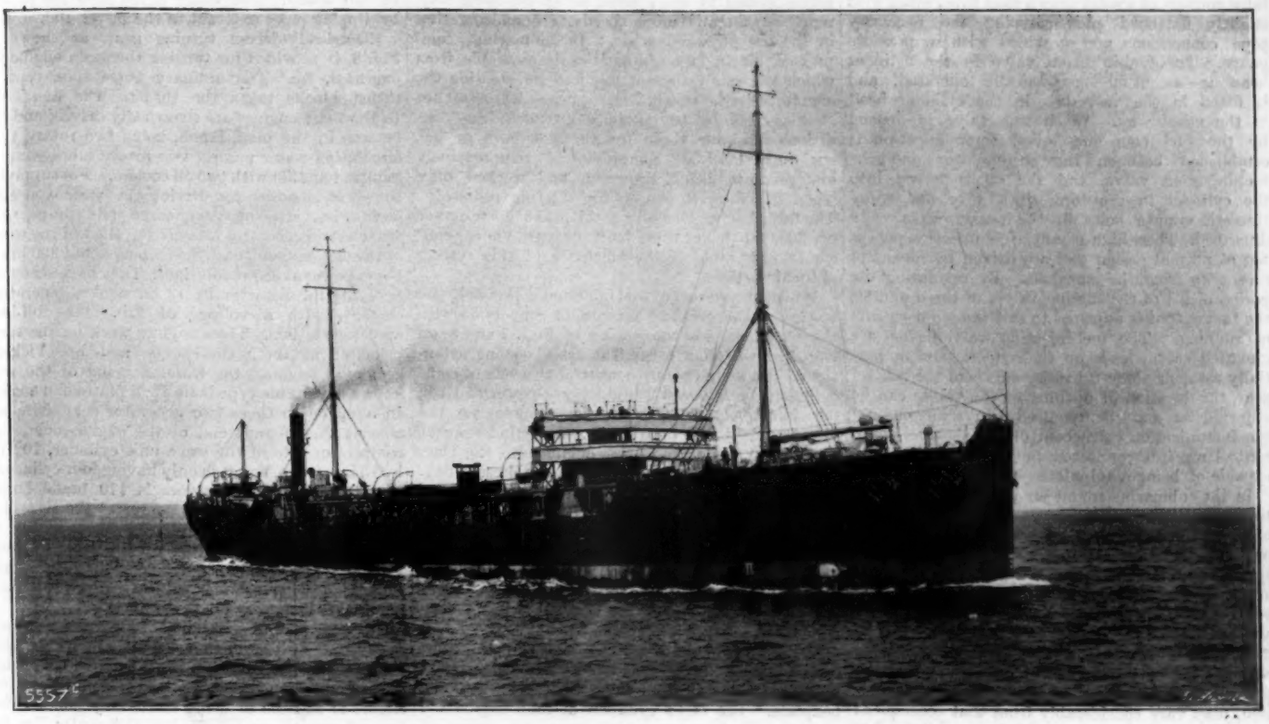


FIG. 1.

as fast as possible. It is an open scientific competition, of great magnitude and backed by unlimited money, and there should be no stable secrets, as of Newmarket.

The warnings of an old Lardner are not required to-day in this uncommercial race. The warnings he pronounced were for the benefit of a Chamber of Commerce; but his memory has been bitterly assailed because he came to the protection of the public from loss of money in unsound, uncommercial schemes. The whole history of the origin of steam navigation requires rewriting, to serve as a contrast to the events of to-day.

THE MOTOR SHIP "SANTA MARGHERITA."

WE illustrate on Plate LIV., and on page 706, the machinery equipment of the Diesel-engine driven oil tank vessel Santa Margherita, which was designed, built and engined by Messrs. Vickers, Limited, at their Naval Construction Works, Barrow-in-Furness. The dimensions selected by the builders to meet the stipulated requirements of the British Admiralty in regard to stability, draught and trim, freeboard and deadweight capacity are as follows: Length between perpendiculars, 440 ft.; breadth moulded, 54 ft.; depth moulded (upper deck), 36 ft. 6 in.; maximum draught, 28 ft. 0¼ in.—displacement at above draught 14,750 tons; total deadweight capacity, 9,916 tons; total bunker capacity, 915 tons of oil fuel.

The vessel is designed to carry a normal cargo of 8,000 tons of oil, in addition to 450 tons of fuel, with full allowance for stores, fresh water, &c., on a draught not exceeding 26 ft.

The hull is constructed on the Isherwood longitudinal frame system to the highest class in Lloyds, with continuous upper and tank decks, and a long poop and forecastle, having fore and aft gangways communicating between the poop and the forecastle.

The appearance of the vessel when running at full power can be seen from Fig. 1, on the present page, from which it will be clear that the twin-screw propelling machinery is installed aft, as is normal practice with tank vessels. Immediately forward of the machinery space, as indicated in Figs. 2 and 3, and separated therefrom by a cofferdam, are placed the fuel bunkers and the compartments containing the main pumps for handling the fuel oil cargo. The main cargo space consists of 10 tanks divided into pairs by a longitudinal centre line bulkhead. The remaining space forward of the cargo tanks is divided into deep-water ballast tanks and a cargo hold. The 'tween deck spaces over the oil tanks at the sides of the expansion trunks are arranged for water ballast and reserve oil fuel. There are two sets of electrically driven cargo pumps of the reciprocating type, as shown in Figs. 2 and 3, which deal with the pumping of the oil fuel, and are each capable of pumping 150 tons of oil per hour under normal working conditions. The oil is drawn from the tanks through two lines of piping and delivered into two deck lines of piping extending right forward and aft. Provision is made for delivering oil at sea to other vessels, and a complete outfit of flexible bronze hose, wire ropes and travellers is carried on board. Branches are fitted on the deck lines of piping so that the oil may be discharged either over the bow or the stern, or over the sides. Arrangements are provided for ventilating the oil tanks by means of an electrically-driven fan, supplying air through the suction pipe lines.

Accommodation is provided for the officers in a large deck-house amidships, the crew being berthed under the forecastle. The engineers are accommodated under the poop, where there are also large workshops and stores.

Two steel masts, with telescopic top masts, are fitted carrying the wireless telegraphy apparatus. The forward windlass machinery, supplied by Messrs. Harfield and Co., has two cable holders and a capstan head on the forecastle deck operated through vertical spindles by machinery below deck, all arranged to handle 2½-in. cable. The power of the motor is 125 brake horse-power, when running at 300 r.p.m. The steering gear of the Williams-Janney electro-hydraulic type was supplied by Messrs. Brown Brothers, and has telemotor control. There are two electric capstans aft, each capable of hauling 8 tons at 40 ft. per minute, and one 8-ton and one 3-ton electric deck winch. Four centrifugal ballast pumps are fitted in separate compartments, each capable of delivering 300 tons of water per hour. The vessel on trial attained a speed of 11 knots as the mean of four runs on the measured mile when loaded to a mean draught of 25 ft. 9 in.

The chief feature of interest in connection with this vessel, undoubtedly, is the main machinery equipment, which is entirely oil-driven. All the principal units are Vickers' Diesel oil engines working on the Vickers patented system of mechanical fuel injection. As very few particulars of this system have been published, it will be of interest to describe generally the leading features. The outstanding point is that compressed air is not utilised for the atomising and the spraying of the fuel into the working cylinders, so that no air compressor is required as an integral part of the engine. The development of this system of injection has been the subject of much experimental work, research and investigation on the part of the Vickers Company, and the system has been used on their Diesel engines for the last eight years. As with all Diesel engines, the heat generated by the compression of air on the compression stroke in the main cylinder ignites the fuel which in the Vickers' system is injected by pressure alone. The object of this system of injection is to simplify the engine, and in particular to dispense with the high-pressure air compressor with its attendant coolers, bottles, separators and piping. In the Vickers' mechanical injection system the oil is sufficiently finely sprayed into the combustion chamber of the cylinder by forcing it at a high pressure through minute holes in a special nozzle below the fuel-injection needle valve. The pressure necessary to obtain this result is produced by a pump suitably controlled. In the standard submarine engine each cylinder has a fuel-injection pump to which the fuel flows from the gravity tank. From each pump the oil is discharged at a pressure of from

2,000 lb. to 4,000 lb. per square inch, depending upon the speed and power being generated by the engine, into the pulsator tube (or accumulator) from which it passes through a special strainer to the needle valve in the cylinder head. The accumulator consists of a solid drawn steel tube, fitted with slightly flattened ends carrying the necessary pipe connections and provided with a pressure gauge. The fuel-injection valve in the cylinder head is—as usual—mechanically operated, and is fitted in the valve-box in the cylinder head in the usual way. When this valve is opened by the fuel cam and lever, communication is established between the accumulator and the fuel-injection valve, and the oil is forced into the cylinder in the form of a very fine spray through minute holes in the nozzle, as already described. These high-pressure fuel-injection pumps are of normal design and are driven by means of eccentrics from the camshaft. By regulating the period of lift of the suction valves of these pumps, the fuel output is adjusted to suit the requirements of running. The fuel-injection valve levers are mounted eccentrically on their fulcra, and by partially rotating these fulcra by means of the control gear, the duration of opening of the valves can be adjusted as may be required. In some engines the fuel-injection valve control and the fuel pump control are interconnected, but generally they are capable of being manipulated independently.

In the submarine engine an arrangement is fitted to the fuel camshaft by means of which the period of fuel injection into the cylinders can be advanced or retarded to give the best working at all load-speed ratios. This forms a convenient means of adjusting the injection to the best advantage, and enables the engine to run most economically under all conditions which arise in service. It may be mentioned that in submarines the engines may be charging the batteries while under way, so that the power developed at any particular speed of revolution, may vary considerably from that consequent upon the speed of revolution of the propeller. For ordinary service this independent timing gear is often omitted, and the control gear is so designed that on adjusting the duration of the injection valve opening, the point of injection is automatically corrected to that most suitable for the duty indicated.

The system is capable of variation, and in some cases there may only be one high-pressure fuel-injection pump for two or more cylinders, and these pumps may feed a high-pressure main or pipe line which has branches leading to the cylinder injection valves. This last arrangement reduces the injection to its simplest terms, and in the latest engines the gear consists of a multi-plunger feed pump discharging to a pressure main from which the fuel is supplied to the cylinders, a single common lever, adjusting the commencing of injection and the period of injection. No needle cocks are required in the pipe lines to distribute the fuel equally amongst the various cylinders, as is the case with air-injection engines.

The chief advantages claimed for this system of injection may be stated as follows:—(1) The elimination of the fuel injection air compressor which, as is well known, has given rise to many of the troubles experienced with Diesel engines. (2) The low consumption of fuel which, on extensive full-power trials, has been as low as 0·38 lb. per brake horse-power per hour. (3) Increased safety in working, due to the removal of the compressor, and high-pressure air reservoir and pipes, which are liable to deterioration due to erosion, &c., especially where high duty engines are fitted in confined spaces. (4) The reduction of the space required, weight and cost, due to the elimination of the injection-air compressor. (5) Less blast effect upon the piston and the cylinder head. With normal air injection Diesel engines the expansion of fuel-injection air from 800 lb. or 1,000 lb. per square inch down to the compression pressure, is accompanied by a drop in temperature, and has a cooling effect upon the contents of the cylinder, which must be counteracted by carrying the compression to a higher figure (some 450 lb. to 500 lb. per square inch) than would be required for the ignition of the injected fuel. With the mechanical system of fuel spraying, no injection air being present, a much lower compression suffices to ensure that ignition shall be certain and immediate under all working conditions. The lower compression which suffices for the Vickers' system makes the starting of the engine, which is accomplished by compressed air in the usual way, more certain and more speedy, economising thus in the use of starting air. In submarines, compressed air in large quantities is available from which the small amount required for starting the engines, may be taken. For services where air for starting has to be specially provided, the conditions resemble those for the hot bulb or gas engine, a small air compressor of comparatively low pressure being provided, and worked only when necessary to charge the starting reservoirs. The fact that engines of a total brake horse-power of 390,000 have been built or are under construction is proof of the efficiency of this system of fuel injection.

Whilst the system of fuel injection is probably the feature of the greatest interest in connection with these engines, an examination of Figs. 7 and 8, on page 716, will show other features deserving attention. The main engines consist of two sets of eight cylinders, giving each a brake horse-power of 1,250 (or collectively 2,500 brake horse-power) for the vessel. The brake horse-power per cylinder works out at 156, which puts this engine into the class of high-powered marine engines of the present day. The cylinders have a diameter of 20¾ in., and a stroke of 33 in., and the full power is developed at 140 r.p.m. At full speed the piston speed will be seen to be the moderate figure of 770 ft. per minute, and the mean effective pressure within the cylinders on a brake horse-power basis, comes out at 79·25 lb. per square inch, showing a very moderate rating of the engine.

The main framing of the engine resembles steam-engine practice, in that the tension loads are carried by forged columns from the cylinder heads to the bedplate. The eight cylinders of each engine are divided into four groups of two, each group of two having six columns. The guides, of which there are two per cylinder, are carried by means of forgings from the main vertical columns, and the vertical columns are braced athwartships by diagonal bracing as shown in Fig. 8. This construction was followed to gain experience of the light cruiser type of engine.

As regards the main running parts, viz., piston rod, connecting rod, guides, slippers, &c., marine-engine practice has been closely followed. The engines, as is usual with Diesel engine practice, are force lubricated, and the crank chambers are enclosed as shown in Figs. 7 and 8 by light sheet-metal guards to prevent oil splash. Each cylinder head accommodates four valves—one inlet, one exhaust, one fuel injection and one N.R.V. for admission of starting air. The inlet and the exhaust valves are actuated by means of pull rods as shown in Fig. 8. The camshaft is driven by the usual vertical shaft and bevel gearing from the crankshaft; and the cam levers are mounted eccentrically upon their fulcrum shaft for the purpose of reversing the main engine. The reversal of the valve gear to set the engine for the required direction of rotation is normally carried out by a small servo-motor, although the hand wheel seen in Fig. 8 serves in an emergency, should the servo-motor be out of action through any cause. The servo-motor is controlled by the hand lever and a dial and pointer indicates the setting of the valve gear. The consecutive positions are, eight cylinders on starting air, six on air and two on fuel, four on air and four on fuel, two on air and six on fuel, and eight on fuel. The small hand wheel controls the amount of fuel, and so the power developed and the speed of the engine. There are two fuel pumps for the eight working cylinders. These two pumps deliver to a common delivery main, from which pipes are led to the eight cylinders. This system corresponds to the simpler system as described already in connection with the mechanical injection, except that the fuel injection is regulated by sliding the taper fuel cam along the camshaft. The cylinder heads are of cast steel. Each cylinder has a separate liner of cast-iron, and a water jacket of sheet steel.

The lubricators for lubricating the main cylinders can be seen in the centre of the engine in Fig. 7, as can also the water service for the cylinder jackets and the water jacket exhaust pipe with its cleaning doors and expansion joints. The pistons are cooled by salt water. The water is led into the pistons by dipping pipes external to the piston rod.

Electrically-driven turning gear, as shown in Fig. 8, is provided for turning the main engine for overhaul, &c. The ordinary horse shoe type of thrust blocks takes the thrust. The auxiliaries to the main engines are electrically driven, and can be seen in the plan, Fig. 3, being two rotary type circulating water pumps, two rotary lubricating oil pumps, together with two oil coolers. For supplying the electric power for driving the various electric auxiliaries, steering gear, cargo oil pumps, &c., two electric generator sets are installed in the wings of the engine-room, each developing about 290 brake horse-power at 380 revolutions. They have six cylinders 10¼ in. diameter by 13 in. stroke, generating current, with a voltage of 220. The full-load amperage is 900. These engines work on the same principle as the main engine, and are Vickers' heavy oil engines, the framing being of the well known submarine type built up of plates and angles. In addition to these two generator sets there are also at the forward end of the engine-room, two compressor sets of the same unit cylinder, 10¼ in. by 13 in. stroke, but each only having four cylinders. The power of these engines is 170 brake horse-power. These compressors compress the air which is stored in the air reservoirs as shown in Fig. 5, and is utilised for starting up the main engines. This air is stored at 600 lb. per square inch, but the engines will start with pressures down to 120 lb. per square inch.

To cover for the possibility of losing all the compressed air in the engine-room there is installed between the two thrusts a small semi-Diesel engine driving an air compressor. This semi-Diesel oil engine is capable of being started by hand. Two fuel oil pumps are installed in the centre line for drawing fuel from the double bottoms and pumping into the "ready use" fuel oil tanks, each of 400 cub. ft. capacity, as shown in Fig. 2. Two "Cochrane" type boilers are installed for steam heating and for steaming out the oil tanks. The uptakes from these boilers are led into the large funnel, the main engine exhausts being separate.

Certain difficulties have naturally had to be overcome during the several years which this vessel has been at sea, and it is commendable on the part of the builders that they are willing to give to the engineering world the benefits of their experience with this installation.

The engines ran well in home waters, but after ten months gave trouble, mainly due to the ship being transferred to service including trips in a shallow, muddy river in the Far East, for which no arrangements were made in the design, the result being that the water spaces became filled with sand and mud deposit. Owing to the circumstances of the service and war conditions it was difficult to carry out the overhaul thereby required, and the vessel has been run for the last twelve months or thereabout at reduced power. Another trouble experienced was in connection with the piston-cooling water system, the glands of the dipping pipes which conduct the water to and from the piston crowns developing leaks, probably accelerated by the grit in the cooling water. It should be noted in this connection that owing to the engine being designed on "Cruiser" lines the space available for the fitting of these glands was very limited, and in the purely commercial type of engine, where the same limitations do not exist, no difficulty should arise. A certain amount of the leakage found its way to the cylinder walls, which resulted in rusting and salting up of the piston rings, causing leakage past the pistons. This, in turn, lead to the atmosphere in the engine room becoming impregnated with oil which deposited in the electric generators. As these generators supplied the power for all auxiliary purposes the trouble was cumulative and, in the severe climatic conditions, threw a heavy strain on the engine-room staff.

The experience which has been gained by Messrs. Vickers in this and other slightly smaller engines

APPLICATIONS OF THE WILLIAMS-JANNEY VARIABLE SPEED GEAR.

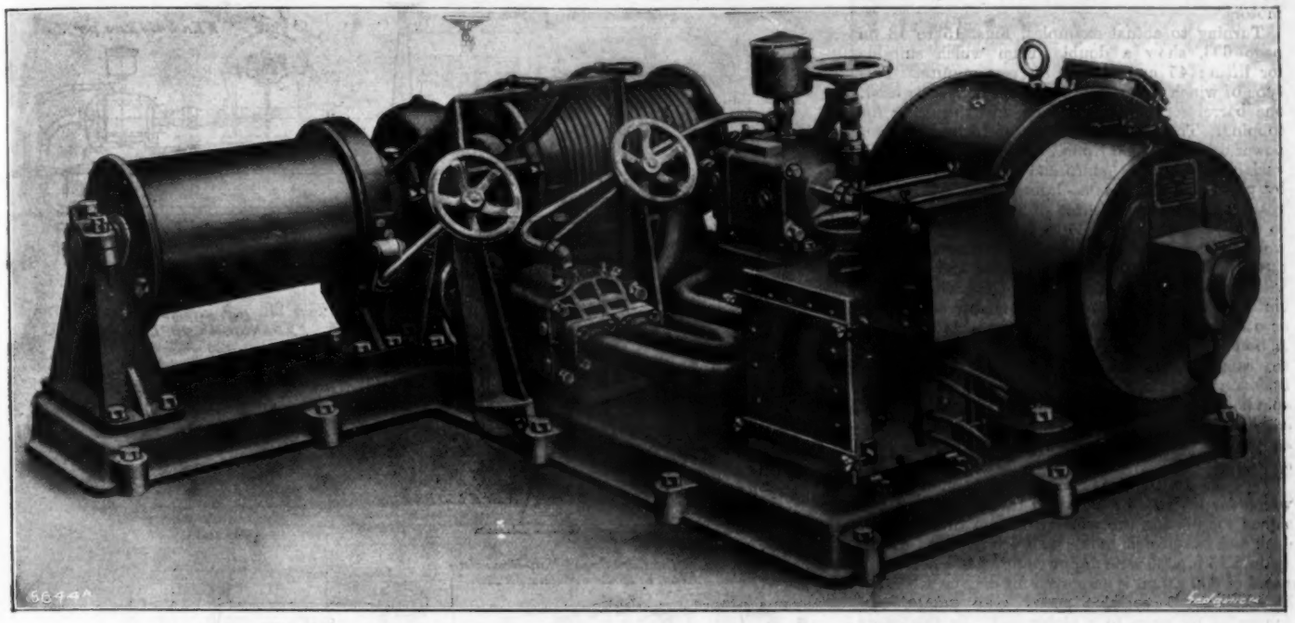


FIG. 15.

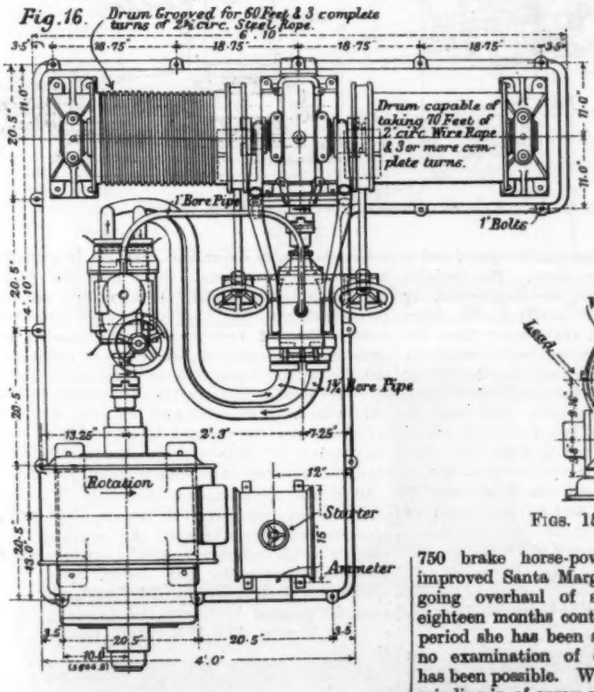
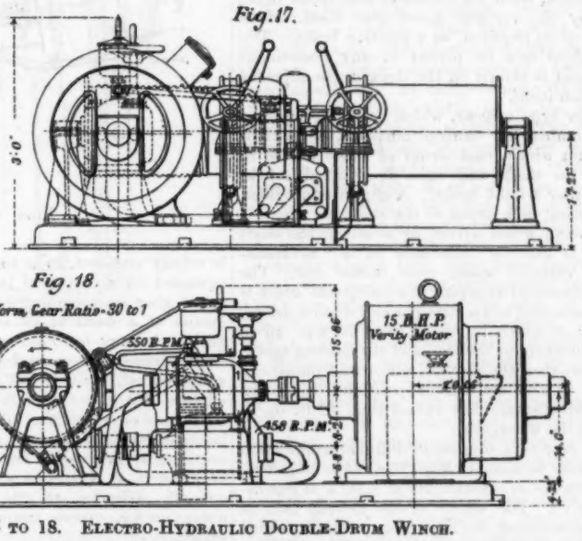


Fig. 16.
Drum Grooved for 60 Feet & 3 complete turns of 2½ circ. Steel Rope.
Drum capable of taking 70 Feet of 2" circ. Wire Rope & 3 or more complete turns.
1" Bore Pipe
1" Bolts
1½" Bore Pipe
Rotation
Starter
Ammeter



FIGS. 15 TO 18. ELECTRO-HYDRAULIC DOUBLE-DRUM WINCH.

built on similar lines, has proved very valuable in the development of their design of Diesel engines for mercantile work, of which they have now a pair of 1,250 brake horse-power engines in hand for an oil tanker for the Anglo-American Oil Company. These latter engines are six cylinder engines with mechanical injection, but the construction of these purely commercial engines is different, a departure being made from the forged column structure followed, to save weight, in the "Cruiser" design. The extra space available has permitted, moreover, of considerable simplification of the engine as a whole.

It may be of interest to note that the Trefoil, an oil tanker fitted by Messrs. Vickers with two 750 brake horse-power, 150 r.p.m. engines, of improved Santa Margherita design, is now undergoing overhaul of steam auxiliary plant after eighteen months continuous running. During this period she has been so constantly under way that no examination of oil-engine pistons or valves has been possible. With the exception of occasional grinding-in of spray valves the only valve touched was one exhaust valve, the spindle of which required easing. No bearings required attention, and the engines at the time of refit were running even better than on commissioning, the ordinary Navy Texas and similar fuel being used. This is a remarkable record of which the makers of the engines and the engineering staff of the ship have reason to be proud.

APPLICATIONS OF THE WILLIAMS-JANNEY VARIABLE-SPEED GEAR.

(*Continued from page* 666.)

LEAVING the subject of the application of the Williams-Janney gear to steering-gears, which was dealt with at some length in our last article, we now propose to illustrate various applications to winches and cognate appliances. The examples we deal with have been supplied in large numbers to H.M. Government and private firms for a variety of purposes. The principal advantages which are claimed for the Williams-Janney gear applied to winches are:—

1. The ability to separate the units of the winch by any reasonable distance, and yet have the control in the most desirable position, either at the winch itself or in a commanding position, such as the operating platform on the deck of a ship.

2. The absolutely positive and easy control at all loads and speeds.

3. The infinite range of speed obtainable in either direction from zero to the speed of the motor.

4. The high starting torque available, amounting to at least three times the normal torque.

5. Absence of shock on the working parts and steady pull on the rope at all speeds, together with quick but smooth acceleration.

6. Silent running of all parts of the winch and driving gear.

7. Absence of complicated electrical controllers, and the use of the simplest form of shunt-wound motors.

Turning to actual examples, Figs. 15 to 18 on page 693, show a double drum winch suitable for lifting 45 cwt. at 60 ft. per minute. This type of winch is employed where a derrick is used, one barrel serving for hoisting and the other for topping. The electric motor is of 15 brake horse-power driving at 600 r.p.m., a "Williams-Janney" variable speed gear pump end which is connected by pipes to a "Williams-Janney" variable speed gear motor end, the shaft of which is connected to the worm shaft of a 30 to 1 reduction gear, the worm wheel being keyed to the spindle on which the drums are mounted. The drums are provided with clutch teeth suitable for engaging with sliding clutches on the drum spindle to enable either one or other drum, or both, to be driven as required. A band brake is fitted to each drum for holding the same when in the de-clutched position. The brakes are operated by a hand-wheel and screwed spindle, the former being placed in a position convenient to the clutch-operating levers as well as to the operating hand-wheel of the variable speed gear.

Figs. 19 to 21 annexed, show a single drum winch for lifting 45 cwt. at 60 ft. per minute, designed for placing the winch drum on the weather deck and the electric motor on a deck below. Here again a 15 h.p. electric motor running at a constant speed of 600 r.p.m. is employed for driving a "Williams-Janney" variable speed gear pump end connected by pipes to a motor end. In this case the ordinary brakes are dispensed with, the whole of the control, both for direction and speed being effected by the variable speed gear itself, which also acts, when required, as a positive brake. The control wheel can be placed in any convenient position, and is shown on the drawing as adjacent to the winch itself.

A further type of gear, which has been supplied in large numbers for haulage purposes, consists of a four-drum winch, each drum of which is free to rotate on the shaft, and when de-clutched is held in position by a light brake. A clutch is provided for connecting each drum to the shaft, to which is keyed a worm wheel driven by a worm, the shaft of which is directly connected to a "Williams-Janney" variable speed gear motor end. The latter is connected by piping to a pump end which is directly connected to a constant speed electric motor, the power of which is varied from 20 h.p. up to 35 h.p., according to the load and the hauling speed. In this case also, the electric motor and pump can be placed in any convenient position. In actual practice this distance has varied from 10 ft. up to 50 ft. from the winch itself.

Coming now to a somewhat different application reference may be made to Figs. 22 to 24 on page 695, which illustrate a capstan fitted with a Williams-Janney drive. The whole of the driving gear is placed underground, the operation being controlled by a pedal so that the operator has both hands free for hauling in the slack. A 7½ h.p. alternating current motor is used for driving the "Williams-Janney" pump end, the motor end shaft driving the capstan spindle through a totally enclosed worm gear. By reason of the high starting torque obtainable, coupled with an infinitely slow speed on the capstan, a steady pull equal to three times the normal load can be obtained on the hawser or rope, whilst any speed from zero up to the maximum speed of the capstan can be got without stops or gradations. Capstans of this type are used with success for hauling trucks up to 50 tons at speeds up to four miles per hour.

A further application, which has been made, and which may be mentioned is a boat-hoisting winch for lifting boats weighing up to 18 tons at 30 ft. per minute. The electric motor is of 85 brake horse-power, and is directly coupled to a variable speed gear, the motor end shaft of which is connected to a worm shaft driving a bronze worm-wheel mounted on a shaft which carries the main spur pinion gearing in a large spur wheel keyed to the hoisting drum. The whole of the gear

THE WILLIAMS-JANNEY VARIABLE-SPEED GEAR.

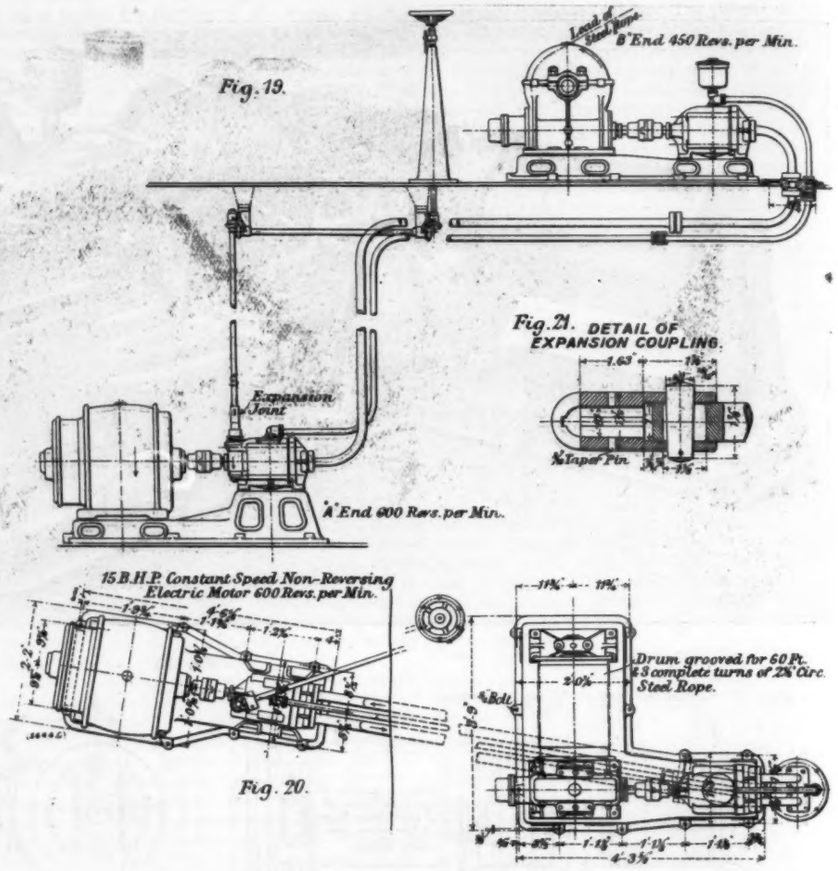


Fig. 19.
Lead of Steel Rope
B End 450 Revs. per Min.
Fig. 21. DETAIL OF EXPANSION COUPLING.
1.63"
1"
Expansion Joint
¾ Taper Pin.
A End 600 Revs. per Min.
15 B.H.P. Constant Speed Non-Reversing Electric Motor 600 Revs. per Min.
Drum grooved for 60 Ft. of 3 complete turns of 2¾" Circ. Steel Rope.
Bolt
Fig. 20.

FIGS. 19 TO 21. ELECTRO-HYDRAULIC SINGLE-DRUM WINCH.

is totally enclosed, so as to be weather-proof and is mounted on a cast-steel base-plate. The variable speed gear is controlled from the upper deck by means of a hand-wheel with shafting and mitre gears. It may be observed that, apart from the brake strap on the main drum, no brakes whatever are provided, the whole of the braking effort being effected by the hydraulic variable speed gear, by means of which the full weight of 18 tons can be arrested in a distance of less than 1 ft. when lowering at full speed, and can be held suspended or lowered at will even with the electric current cut off. Winches of this pattern have been in operation for over six years, and have given entire satisfaction.

(To be continued.)

LITERATURE.

Industrial Electrical Measuring Instruments. By KENELM EDGCUMBE, M.Inst.C.E., M.I.E.E. Second edition, revised and enlarged. London: Constable and Co., Limited. [Price 6s. net.]

THE discussion of measuring instruments for any purpose will always find an interested technical audience. Relatively large issues depend upon such instruments, so that knowledge of their construction, and of their probable accuracy, is essential to the engineer.

Where measurement is direct and positive and limited only to human perception, the reduction of error to its smallest dimension is of importance even where practice allows tolerance of some magnitude, but where error is multiplied by the means of measurement initial and permanent accuracy is vital. Exact measurement is the basis of all physical science which progresses in ratio to the refinements of the laboratory. Industrial certitude is also dependent upon its implements of measurement, although these may for practical reasons lack the delicacy of laboratory apparatus. In the electrical field the case is even more prominent. Most of such measuring appliances are in some sense inferential, are of great delicacy, and are dependent upon minute adjustment and care in calibration. The fractional currents employed are influenced in numerous indirect ways, their accuracy may be vitiated by many causes outside the control of their makers, who are anxious to maintain general confidence in their product.

With the application of electricity to industrial use came the necessity for determining quantity, pressure, and resistance in the simplest possible manner with relatively small error, and very uncommon ingenuity has found full scope in applying principles to practice with this end in view. The need has given rise to specialists and a very highly skilled scientific industry is the direct result.

The maker of electrical plant deals mainly with large masses and heavy material; the manufacturer of measuring instruments works in an infra field where he meets with similar problems, greatly accentuated by the small scale of his product. The two industries each are, in one sense, an inversion of each other, but they are nevertheless mutually dependent, reacting upon each other to a common end.

The volume at present under review confines itself to industrial measuring instruments and its author is closely connected with the manufacture of such apparatus. The book is neither elementary nor abstruse; it is informative in the best sense of the term; it assumes some familiarity on the part of the reader with the instruments described, dealing very briefly with principles and abstract

THE WILLIAMS-JANNEY VARIABLE-SPEED GEAR.

(*For Description, see Page* 693.)

Fig. 22.

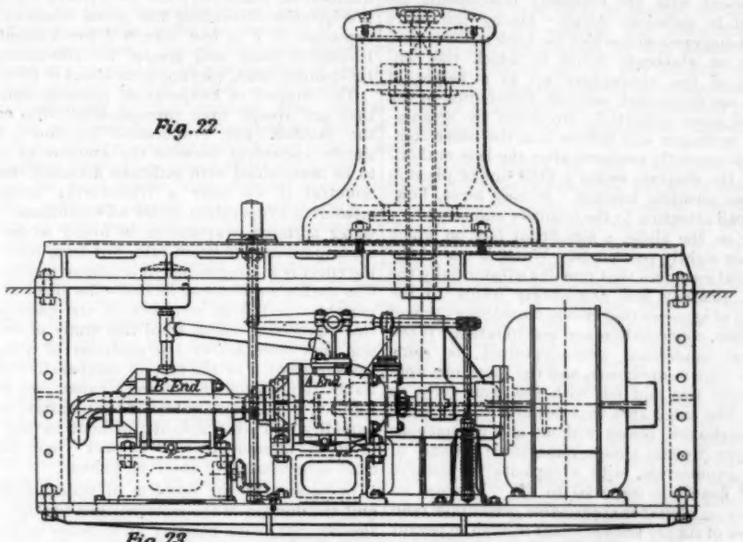
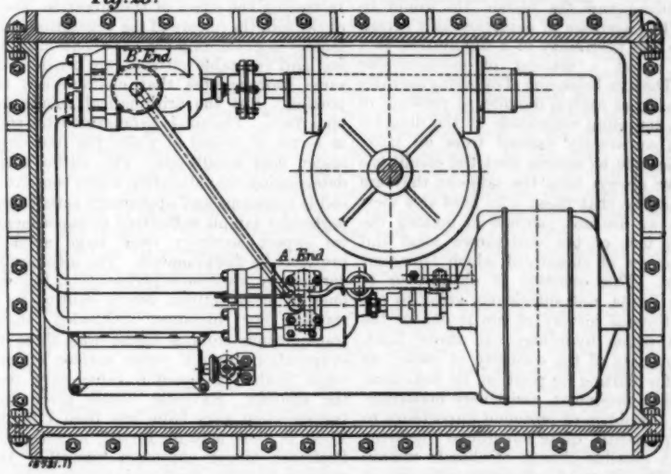
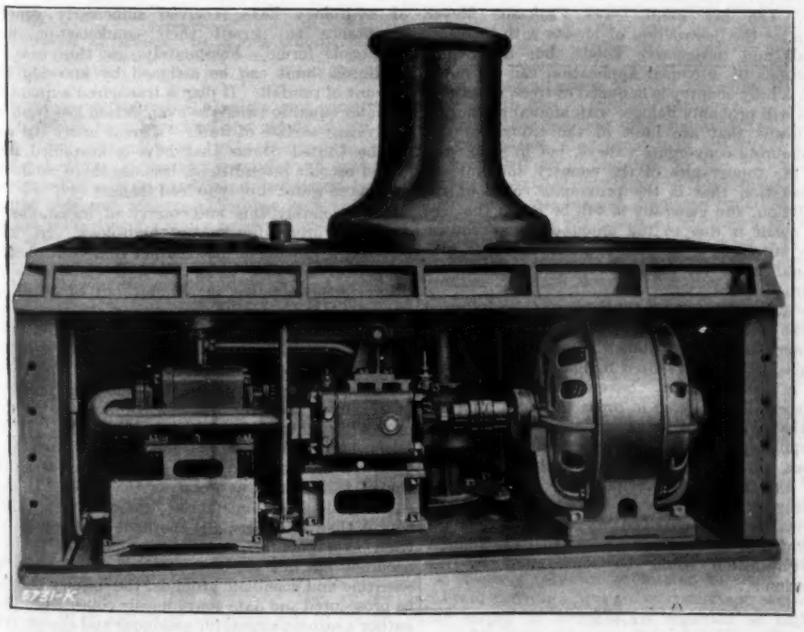


Fig. 23.





FIGS. 22 TO 24. ELECTRO-HYDRAULIC CAPSTAN.

theory, and is thus of a decidedly practical character.

Contrary to what might have been expected in a work of this class, catalogue material is entirely absent, and where reference is made to the products of the author's firm, such mention is quite in impartial relation to other makes.

The whole of the 260 illustrations are diagrammatic and closely pertinent to the text, which fills the remainder of the 405 pages. The method of treatment, subdivision and classification are sequential, and, without being in the least diffuse, the book is easily read and the matter grasped. A full contents table and index add to the reference value of the book, the typography, paper and binding of which leave nothing to be desired. The greatest care is evident throughout, and the author has taken the opportunity afforded by a second edition of altering and amending the first, so that the present issue is no mere reprint, but a genuine revision.

Preliminary to the more specific contents of the book is a section on Errors and Accuracy, in which the practical difficulties and limitations that face the maker are briefly discussed; a table, presumably based on the author's own experience, of the errors usual to given apparatus, is included. Here, as elsewhere, a clear distinction must be drawn between precision and workshop measurements, in the present case between commercial or switchboard, and laboratory apparatus. The errors given by the author for laboratory pattern instruments seem to be unduly high. Such a table must take cognisance of more than initial errors. Instruments of laboratory type are more delicate, they are handled by more discriminating intelligence; it is assumed that errors of instruments in average condition are tabulated.

The distinction between sensitiveness and accuracy is discussed, and since most instruments involve a scale, this practical matter is dealt with. Sources of error are numerous. These may be mechanical, due to temperature, stray magnetic fields, electrostatic effects, or to the inclusion of unnecessary magnetic material. The nature and form of the containing case varies considerably, and in this alone there are many pitfalls. Consideration must be given to the use to which the instrument is to be put as well as to the conditions imposed by the mechanism itself. The author deals briefly with calibration, and from his remarks it would appear that commercial instruments are most often scaled apart from actual test currents. This practice is inferior to that of makers of Bourdon pressure gauges for steam, the scales of which are each independently calibrated.

Mechanical details applicable to all types of instruments are briefly reviewed by the author. Pivots have their own peculiar problems common to makers of watches and wattmeters. It is obvious that frictional resistance must be minimised as far as possible and well-known horological methods are employed.

Damping by electrical means to diminish sensitiveness, and, by minimising fluctuations, to get steady readings, is an interesting subject, which the author deals with in a very practical manner, although it is essentially abstruse. Mechanical damping devices using air or oil to the same end are also taken into consideration.

Permanent magnets have had much patient study, and several first-class minds have investigated their peculiarities. The electrical-instrument maker depends very greatly upon these so that he is deeply interested in the practical application of the knowledge gained by very erudite scientific research. Electro-magnets of small size, giving small fields, are also important details, and the author is very explicit and clear upon this section of his subject, which is treated simply and well.

The permutations and combinations of permanent and electro magnets, the reactions produced by them as moving mechanism, their inductance and resistance, and the relation between current intensity and temperature, all these are among the phenomena which affect the mechanism of electrical measuring devices.

It is a fascinating subject; the field is full of possibilities, even if it is also full of the problems and

imitations of practical workmanship. Naturally voltmeters and ammeters occupy considerable space, but apparatus for the measurement of resistance, insulation, current, potential, pressure and power, are fully treated in the brief method inspired by the space limits of a single volume.

Pyrometers, from their increasing importance, are dealt with rather fully or at least adequately. A section devoted to recorders deals with charts, inking arrangements, and with a grapher made by the author's firm which avoids the use of ink by substituting a typewriter ribbon for the usual pen carriage. This device, which is noticed at some length is of very ingenious construction and is well worth the space devoted to its description.

The last 45 pages of the book deal with a variety of instruments, otherwise unclassified, used for special purposes. One outstanding feature of the book, which deserves particular notice, is its practical tone and the manner of its treatment.

The numerous hints and warnings given are the result of evident experience, and fill a useful purpose on this ground alone.

Although confined to industrial measuring instruments, the book covers an immense field, any single section of which could easily be expanded to a volume at least half the size of the one before us. This puts a premium upon brevity, clear statement and exactitude in presentation.

To survey an entire field in a single volume in the manner that the author has done is a feat of no small magnitude. One could wish that a bibliography, and text references thereto, had been included for the benefit of the reader particularly interested in one section and desirous of obtaining fuller information. The footnotes are no substitute for this, although they have a distinct value, especially the references to articles in the technical press.

The Elements of Hydrology. By ADOLPH F. MEYER, C.E., Associate Professor of Hydraulic Engineering, University of Minnesota. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 18s. 6d. net.]

THE Spaniards have a proverb to the effect that four men are required to make a salad, but a greater number is necessary to give form and completeness to the ingredients that go to make a treatise on hydrology. A meteorologist is needed to measure and describe the precipitation, a geologist to trace the passage of water through the rocks and strata, a chemist to determine the salts carried and the nature of their action, an agriculturist to note the character of the soils and the disappearance of the water through transpiration, a physicist to ascertain the evaporation, an engineer to arrange protective drainage schemes and one might run on through a longer list of specialists, for as water enters into every field of human activity, many are engaged either in the collection, the distribution, or the removal of this necessity. We suspect that it is this universal application of water to all the affairs and business of life, calling for such wide treatment, that has prevented the appearance of a treatise that would commend itself to Professor Meyer's approval. As in meteorology, the investigator here has to deal with many isolated facts that refuse to be related to any general theory, and is compelled to substitute individual treatment for co-ordinated method. The deduction of fundamental laws and deduced relationships are the tasks for a later and better informed judgment. Hydrology, the author says, is a new science, and he might have added that it is now only in the stage of resolving practical problems empirically. It is only later that the study of general conditions becomes an aim in itself.

The author approaches the subject mainly as a hydraulic engineer. He writes for the benefit of teachers and students of engineering in America, but takes an outlook sufficiently wide to make his book useful and informing. All illustrations and examples are drawn from American sources, but the principles and methods of observation remain the same the world over. "An effort has been made to present the elementary subject-matter, accompanied by various methods of analysing and interpreting data, and through these, the elucidation of the fundamental principles of hydrology."

The earlier portion of the book is mainly meteorological. The atmosphere, its gases, its circulation, are discussed. Water vapour, precipitation and evaporation are considered, and the methods of measurement with the necessary instruments are described in sufficient detail. Among the many excellent diagrams with which the book is illustrated, we note an elaborate figure in which the constituents of the atmosphere up to a height of 140 km. are delineated, and the distribution of the contained gases indicated. No doubt the arrangement of hydrogen and helium and the other components is correctly rendered after the best authorities, but the diagram seems a little out of place in a rigorous scientific treatise. It may serve, however, to call attention to the quantity and constancy of water on the globe, a significant fact on which the author rightly comments. Water is one of the few natural resources that remains substantially the same in quantity and availability owing to the balancing of agencies that ensure a recurring cycle of evaporation, condensation and precipitation. When the oldest sandstones were deposited the same processes were in operation, and the raindrops were of the same size and fell with the same force as to-day. The small area that declares the presence of carbon dioxide passes without any conspicuous remark, yet it offers a more remarkable instance of constant equilibrium, with a capacity to preserve a critical condition essential to life. Increase its content by an almost inappreciable percentage (and the sources of supply are abundant enough to permit such an addition) and the higher life would be suppressed. The agencies of depletion also permit us to imagine the possibility of a diminution that would bring about a disaster of inconceivable magnitude. The nice balancing of opposing agencies whether in water, or carbon dioxide, in presence of forces of such imposing magnitude as the diagram indicates, has apparently existed from all time, but it is unscientific to assume that the conditions of climate have always been the same as they are to-day. It may be that those who hold this view are right, but we are not justified in making the assumption in face of the well-known local and permanent changes of climate of which abundant examples exist. This question of change, or of change within limits, not sufficiently great to cut short the continuous history of life is one of the side issues on which hydrology can throw light. The careful estimate of the quantity of water, its opportunities for shifting its position, its behaviour with change of environment, assist very materially in elucidating a problem of profound importance to humanity. Apparently quite superficial questions connected with possible change of climate remain unanswered. The effect of deforestation is one of these. The lay mind, says Professor Meyer, associates the destruction of forests with increased rainfall and destructive floods, but no general deductions of universal application can be made. When a hilly country is denuded of trees, disastrous floods will probably deluge, with annual regularity, any towns that are built in the trough of two neighbouring converging valleys, but in such cases it is the topography of the country and not the deforestation that is the proximate cause of the inundation, and generally it will be found that the final result is due to the union of many causes. Every stream is a problem in itself, and it is with the analysis of the final effects that hydrology is concerned.

The author has treated the subject of precipitation in great detail, and the analysis of many thousands of observations has entailed severe labour. The graphical results presented in maps and diagrams have a distinct value. Severe rain storms have been specially analysed in order to afford information that will be of value in determining channel and spillway capacities. The records from many stations have been combined in such a way as to show the rates of precipitation, which would probably be exceeded in a given space of time, and empirical formulæ derived which best fitted the observational data. It was found that the amount of precipitation could be represented by the expression:

$$Q = \frac{At}{t + B}$$

where Q is the precipitation in inches, t the time in minutes, and A and B are constants. "The frequency of different rates of precipitation varies approximately as $F^{0.2}$, where F represents the number of years between recurrences of rates of precipitation exceeding the given intensity. The exponent of F is less than 0·2 for 5-minute and 10-minute rates, and greater for 100-minute and 120-minute rates, varying from about 0·15 to 0·3."

The subject of evaporation presents difficulties that are absent from precipitation. We can see the rainfall, but evaporation is elusive. Very simple apparatus permits the amount of rainfall to be determined with sufficient accuracy, but it is doubtful if we have a trustworthy method of measuring evaporation under all conditions. From water surfaces evaporation is found to be fairly continuous at a uniform rate, but from land areas, the effect is so irregular as to be almost intermittent. The author's discussion includes the effect of many variables and is as complete as the data permit. One conclusion drawn from this study of evaporation loss foreshadows the abolition of attempted measurement. In the case of comparative shallow water, it is stated that correct values can be best deduced from known values of temperature, relative humidity and wind velocity without having resort to actual measurement. "Correct" here means a close agreement with observed values.

In passing to the problem of transpiration, we quit the domain of the meteorologist for that of the agriculturist, with possibly an increase in interest. In tracing the effect of transpiration, the character of the soil, the nature of the vegetation, and of other factors in promoting the vaporisation of water from leaf and vegetable surfaces, are considered with the same thoroughness that characterises the earlier portion. But the arithmetical results grow more uncertain. The aim is to determine the soil moisture in terms of inches of water per foot depth of soil under field conditions. The author's method of determining the saturation water content of a given soil is ingenious and apparently satisfactory for the particular sample submitted to experiment. But if we expect accuracy over large areas we shall probably be disappointed. The incongruous results derived by various experimenters, following other lines of investigation, advise caution in accepting results. For instance, Schleiden thought the transpiration from a forest was three times the evaporation from a water surface of equal area, while Shübler assigned a value only one-quarter the amount. Extreme values given for annual transpiration vary from less than 1 in. to 16 ft.! There is room here for further investigation, or, as Professor Meyer expresses himself, "It will be years before the fundamental principles and facts of hydrology have received sufficiently general acceptance to permit their condensation into handbook form." Fortunately, in this case, a maximum limit can be assigned by knowing the amount of rainfall. If plants transpired a quantity of water equal to twice the evaporation loss from an equivalent surface of water "a great many streams in the United States that have a sustained flow would become intermittent, because there would be no ground water supply to feed them."

Unfortunately this uncertainty of measurement occurs in other divisions of hydrology. In deep seepage, a process of distribution that controls the supply of artesian wells, we find statements of discrepancies, smaller in amount but of quite an important character in determining the motion of underground water. The inconsistent results arise partly from the nature of the material through which the water flows, varying from impervious clays to coarse gravels; from the amount of pressure head; from the length of soil column, the nature of capillary interstices, and other variables. If we select two well-known authorities as Hazen and Slichter, we shall find that one estimates the discharge three times as great as the other. Under such baffling circumstances, there is no other course than to record the methods and results of tried experimenters, admitting that the desired accuracy has not yet been attained. But on both scientific and economic grounds, the inquiry should be prosecuted and data continuously collected. The author's earnest appeal for assiduous and systematic observation is not likely to fall on deaf ears.

Investigations into the amount of runoff from a watershed supplies valuable information to the engineer, for on the statistics so derived he must rely to define his plans for water power, for irrigation, for municipal needs, or for the provision of an efficient drainage system. Runoff, Professor Meyer argues, must not be regarded as a percentage of the rainfall, and obvious as this caution is, it is often overlooked. Runoff is the residual after the demands for evaporation and transpiration have been satisfied. Heavy irregular rainfall may induce a large surface flow of an intermittent character, giving rise to local floods that demand special precautions, while an equally heavy precipitation in the form of snow may melt slowly and percolate through the soil as seepage flow, exhibiting little sign of runoff. Practically what is wanted for public utility is the knowledge of the extent and the frequency of occurrence of extreme floods. This knowledge is best acquired by a study of the most intense rainstorms in the country, embracing material derived from the nature of the watershed area, the average precipitation and distribution, and the character of stream flow. The discussion of this last factor, together with the examples of floods and rainstorms furnished by the author add very much to the value of the treatise. But it must be remembered that floods on large streams cannot be prevented. These are as inevitable as thunder storms and equally out of control. The best that can possibly be done is to diminish overflow by confining the flood water by means of levees and by straightening and enlarging the channel at critical points. Reservoir storage is utterly inadequate on account of the enormous quantities of water involved. The ineffectiveness of such measures is well illustrated by the 1912 flood on the Mississippi. When the river at Cairo had risen 50 ft., the Upper Mississippi was contributing less than the thousandth part. The Ohio at Pittsburgh, and the Missouri at St. Joseph, added each less than the hundredth part. "If all the water of these tributaries at the points mentioned had been held back by reservoirs the water in the river at Cairo would have been lowered only a few inches in a 50-ft. flood." The construction of "check dams" is mentioned as a useful precautionary measure. These are relatively small, simple and inexpensive structures, consisting mainly of loose rock. Their object is to retard the flow of water down the ravines and canyons, that comprise the upper watersheds of torrential streams, reducing erosion and encouraging the absorption of water at the mouths of the canyons. In California, where the rivers occasionally fall 6,000 ft. in 40 miles, the construction of check dams has been attended with very happy results.

On the Nature of Things. By HUGO WOODS, M.D. B.A., F.C.S. Bristol: John Wright and Sons Limited; London: Simpkin and Co. [Price 10s. 6d. net.]

SPECULATION concerning the origin and constitution of matter have exercised the minds of philosophers from antiquity to the present day. Of these conjectures, those that regarded all matter as composed of minute particles, called atoms, have attracted the most attention, because such notions approach nearest to generally received views. The name of Lucretius is more particularly connected with these theories, some of his suggestions come very near to being prophetic, and indicate an insight into some of the principal properties which we attribute to-day to the physical atom. There is, however, a profound difference between the vague utterances of a poetic imagination and the rigorous demonstrations of experimental science. The assertions of Lucretius, however ingenious and far-sighted, were "spider wove from his own brain," they rest on no substantial foundation, but modern theories are supported by cumulative evidence that carry the certainty of conviction, though in such an intricate problem as the constitution of matter, the selection of a decisive hypothesis that explains all phenomena may not yet be possible. While there is room for alternative explanations, we may expect to see ancient theories revived and new constructions put on old sayings. The author is anxious to do justice to Lucretius and to uphold his claim to consideration, but in his desire to demonstrate that ancient speculators anticipated modern inquiry, he disregards the essential difference originating in the methods of inquiry and the "weight" that attaches to each. The notion that electricity could give birth to matter, or that the whole mass of the electron was electromagnetic was necessarily unglimpsed by the ancients. To attempt to reconcile ancient and modern views is to undertake a task as difficult as to accommodate the Jewish cosmogony to the planetesimal scheme of Chamberlin or the mathematical inferences of Jeans.

The author insists on the correctness of the essential doctrines of Lucretius, but we do not think he has proved his thesis, and, moreover, the position which Dr. Woods occupies is very difficult to understand. We are not sure that we have grasped correctly what he means by an atom, and at times there is apparently some confusion between an atom and a molecule. A chemical atom is, however, explicitly defined as the "largest particle of a given element which exists without intrusion into its substance of ether gas." Owing to the researches of Sir J. J. Thomson, Rutherford and others, a very different mental picture of the atom has been formed. From the modern point of view it is regarded as an elaborate structure, possessing a nucleus or source of positive electricity with a ring system of many electrons, at great distances from each other in comparison with their dimensions. There is, therefore, a fundamental difference in the way the subject is approached.

From the atoms the author proceeds to build up molecules. These latter consist of atoms "whose surfaces adhere, like plates, owing to the lower pressure of the ether gas intervening between the flat surfaces of the atoms as compared with the pressure outside." The shape of the atom determines in great measure the chemical properties of the combination. If the atom be hemispherical "it will obviously combine with one other atom only—or, in chemical language be monovalent. If the atom is shaped like a penny or has two flat surfaces, it will be divalent . . . If we regard oxygen atoms as being shaped like pence, the bulk of each atom being 16 times that of an atom of hydrogen, water molecules will be like pence with a hemispherical atom of smaller size attached firmly to each flat surface of the atoms of oxygen, shaped like pennies." Again, we meet with a striking difference in the mechanical explanation of valency, and those who are accustomed to attribute this phenomenon to the behaviour of the electrons forming the outer rings of the atom will perhaps be unable to accept the author's explanation.

In the part assigned to the ether gas we must most decidedly separate ourselves from the author's expressed views. Whether ether be a convenient fiction, created to explain some baffling phenomena, or whether it be an invisible, intangible, medium filling all space, it is of the most elusive character. It was a surprise, therefore, to learn that this ether gas had been submitted to such close examination, that the size of the atoms had been estimated as in the case of the "so-called electrons or atoms of electricity." Notwithstanding the success of this inquiry, implying isolation and exact knowledge of the nature of the gas, it is hard to understand that the source of electricity is to be traced to the movements of the ether "arising from differences of density in adjacent masses of it" Still more wonderful is the explanation of earthquakes, wherein it would seem that ether can act as escaping steam, and that the rush of this gas from regions of high pressure to regions of low, through or within the crust of the earth, produces the violent disturbances that we call earthquakes. There is no need to invoke an ether gas when so many agents capable of producing the observed effects are known to be at work.

Heat, light, magnetism, sound, all pass under the author's examination, and though much is urged that is new or unexpected, the result is not edifying. Gravitation and astronomy come under review, and it occasions no surprise that the supposed existence of a property inherent in matter, whereby it is capable of exerting a power of attraction across space, either empty or occupied, is regarded as highly improbable, and consequently untenable. Though we are in the humiliating position of having to accept the fact of gravitational attraction without being able to offer an explanation, we are disinclined to accept the author's reasoning, mainly, perhaps, because we cannot understand it. The principal feature of the explanation consists in assuming a cyclonic movement in a gas of incompressible atoms which fills interstellar space, but how this cyclonic movement explains motion about a central mass must be decided by a reference to the volume itself.

BOOKS RECEIVED.

Fourth Report of the Corrosion Committee of the Institute of Metals. By GUY D. BENGOUGH, M.A., D.Sc., and O. F. HUDSON, A.R.C.S., London: Published by the Institute, 36, Victoria-street, S.W. 1. [Price 12s. 6d.]

Sell's Directory of Registered Telegraphic Addresses. With Telephone Numbers and Classified Trades. By HENRY SELL. London: Business Directories, Limited. [Price 30s.]

The Woman's Motor Manual. By GLADYS DE HAVILLAND. London: Temple Press, Limited. [Price 3s. net.]

Annual Report and Lectures: The Keighley Association of Engineers, 1917–18. Keighley: The Keighley Printers, Limited. [Price 1s.]

Tables of British Decimal Coinage, Metric and British Weights and Measures. (In English and Italian.) By A. J. LAWSON, M.Inst.C.E. London: Eyre and Spottiswoode, Limited.

Things a Sailor Needs to Know. By Captain D. WILSON-BARKER, R.D., R.N.R. London: Charles Griffin and Co., Limited.

The Shipbuilding Industry. By ROY WILLMARTH KELLY and FREDERICK J. ALLEN. With an Introduction by CHARLES M. SCHWAB. Boston and New York: Houghton Mifflin Company; London: Constable and Co., Limited. [Price 12s. net.]

Fuel Research Board: Special Report No. 1. Pulverised Coal Systems in America. By LEONARD C. HARVEY. London: Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office. [Price 2s. 6d. net.]

Cotton Spinning. By WILLIAM SCOTT TAGGART, M.I.Mech.E. Volume I *Including all processes up to the end of carding.* Sixth Edition. London: Macmillan and Co., Limited. [Price 7s. 6d. net.]

A Manual of Machine Designs. By FRANK CASTLE, M.I.Mech.E. London: Macmillan and Co., Limited. [Price 7s. 6d. net.]

Les Applications de la Physique pendant la Guerre. Par H. VIGNERON. Paris: Masson et Cie. [Price 7 francs net.]

A Text-Book of Heat and Heat Engines. By ANDREW JAMIESON, M.Inst.C.E. Volume I. Eighteenth Edition. Revised by EDWARD S. ANDREWS, B.Sc. (Lond.). London: Charles Griffin and Co., Limited. [Price 8s. 6d. net.]

Elementary Manual on Heat Engines, Steam, Gas and Oil. By ANDREW JAMIESON, M.Inst.C.E. Sixteenth Edition. Revised by EWART S. ANDREWS, B.Sc. (Lond.). London: Charles Griffin and Co., Limited. [Price 5s. net.]

The Book of the Ford. By R. T. NICHOLSON, M.A. Fourth Edition. London: Temple Press, Limited. [Price 2s. net.]

Directory of Paper Makers of the United Kingdom for 1919. London: Marchant, Singer and Co. [Price 2s. net.]

"The Electrician" Directory and Handbook of the Electrical Engineering and Allied Trades, 1919. Thirty-seventh Edition. London: Benn Brothers, Limited. [Price 15s. net.]

Aeroplane Construction: A Handbook on the Various Methods and Details of Construction Employed in the Building of Aeroplanes. By SYDNEY CAMM. London: Crosby Lockwood and Son. [Price 7s. 6d. net.]

The South and East African Year Book and Guide. Edited annually by A. SAMPLON BROWN, F.R.M.S., and G. GORDON, F.R.C.S. 1919 Edition. London: Sampson Low, Marston and Co., Limited. [Price 2s. 6d.]

The Odyssey of a Torpedoed Tramp. By "Y." London: Constable and Co., Limited. [Price 6s. net.]

Catalogue of Lewis's Medical and Scientific Circulating Library. New Edition. London: H. K. Lewis and Co., Limited. [Price 12s. 6d. net.]

Marine Boiler Management and Construction. By C. E. STROMEYER, M.Inst.C.E. Fifth Edition. London: Longmans, Green and Co. [Price 16s. net.]

THE STRENGTH OF FERRO-CONCRETE VESSELS.—Owing to rumours of less satisfactory experiences with ferro-concrete vessels abroad, a Danish ferro-concrete shipbuilding company has asked the Director of the Norwegian Veritas for his opinion. It may be mentioned in this connection, that the Norwegian Veritas was the first institution of its kind to issue rules for the classification of sea-going ferro-concrete vessels and to classify such vessels. A fair number of ferro-concrete vessels and lighters have been built in Norway to Norwegian Veritas class, so that the institution has some experience with this method of construction. The director has now given expression to an opinion, which reads as follows: In the experience the Norwegian Veritas has had so far with regard to sea-going vessels of ferro-concrete, such vessels have proved themselves technically satisfactory, inasmuch as they have proved watertight and of sufficient strength. There have been no cracks which have caused leakage, and no trouble has been experienced in making the repairs necessary after collision or grounding.

TURBINE-DRIVEN PIPELESS SALVAGE BILGE PUMPS.

CONSTRUCTED BY MESSRS. W. H. ALLEN, SON AND CO., LIMITED, ENGINEERS, BEDFORD.

Fig. 1.

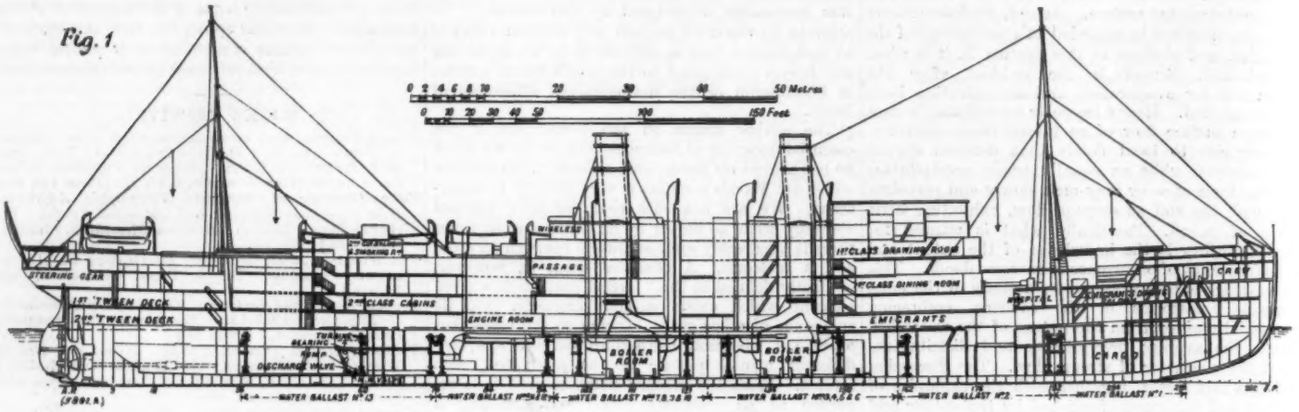


Fig. 2. SECTION THROUGH PUMP & DISCHARGE VALVES.

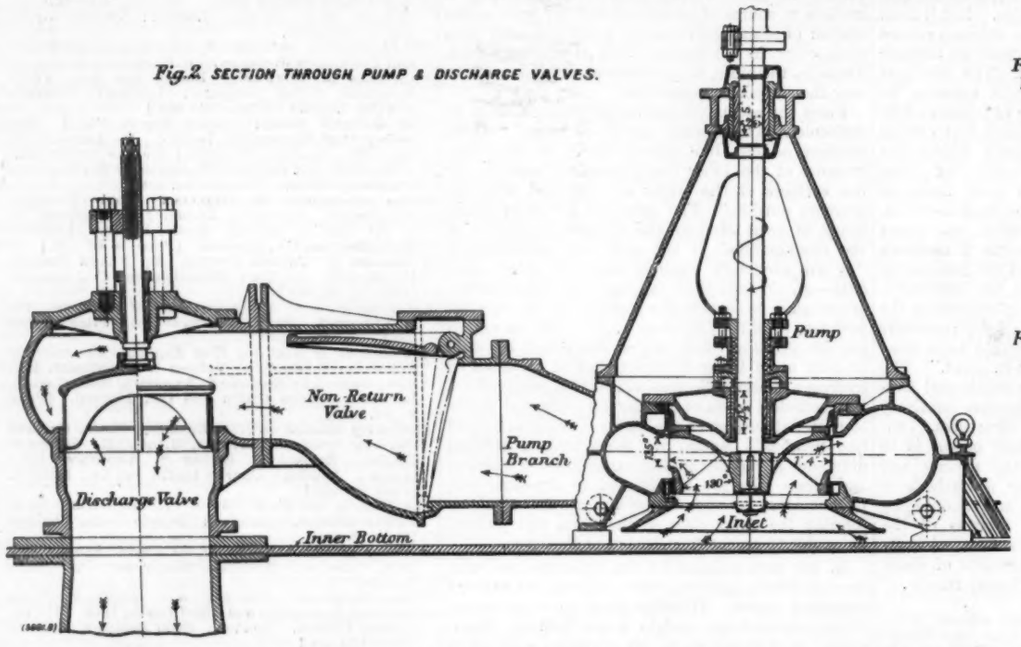


Fig. 3. Constant Head on Pump 25 Feet.

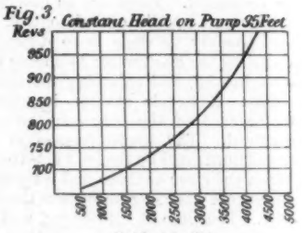
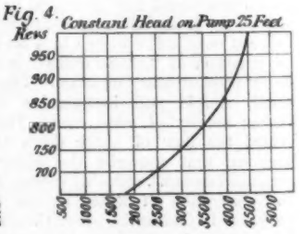


Fig. 4. Constant Head on Pump 25 Feet.



On the present page and page 699, we illustrate the Allen steam turbine-driven pipeless salvage bilge pump with a capacity of 1,000 tons of water per hour. The plant has been specially designed and manufactured during the war by Messrs. W. H. Allen, Son and Co., Limited, of Queen's Engineering Works, Bedford; and has been extensively installed by the Admiralty on all their more recent battleships and fitted as opportunity offered on existing ships. The departure from the more usual type of horizontal salvage pump is due to the great increase in the capacity of the pump. When it was pointed out and eventually decided that a salvage pump of greater output was necessary to cope with the urgent requirements of salvage, the designs were prepared upon the lines of existing types of horizontal pump, but it was soon found that it was not possible in the restricted and out-of-the-way places in which such pumps are usually erected, to find space for the plant with its large and lengthy suction and delivery pipes. It was, therefore, decided to depart entirely from accepted practice and produce a vertical spindle type of direct-driven pump, which has many novel and interesting points—the principal one being that the pump is pipeless, the arrangement enabling it to draw direct from the bilge through a removable strainer and discharge through a non-return valve The stop valve and the cone-piece forming the sea connection are shown in Figs. 2 and 8.

Amongst other advantages are that the pump is self-starting and commences to discharge water on being started up, it occupies little space, the steam turbine is erected well above water line as this only entails a length of shafting between the turbine and the pump, and it is of light weight (about 43 cwt.).

A complete plant is shown in Fig. 5, page 699, and the details of an installation with the pump mounted on the inner bottom of a ship and the steam turbine fixed on a bracket in the upper part of the hold, and well above water-line, is shown in Figs. 6, 7 and 8.

The details of the pump, which is of the firm's "Conqueror" type, with its fittings are shown in Fig. 2. The pump has a single suction disc and gives an output of 1,000 tons of water per hour when running at about 940 r.p.m., and discharging against a head of 35 ft. It is constructed entirely of gun-metal, and the guide bearings are lined with lignum vitæ.

The pump is self-charging, and will start without using the ejector when the level of the water is 8¼ in. above the inner bottom of the ship, while if the pump is provided with a suction bell-mouth it will, when worked in conjunction with the ejector, start pumping when the water is about, but not less than, 1½ in. from the inner bottom, as indicated in Fig. 6. The pumps run quite satisfactorily when submerged or flooded until the water reaches the turbine.

The steam turbine is of the single-stage impulse type, designed for a working steam pressure of 150 lb. per square inch, and may exhaust either direct into the atmosphere or against a back pressure of 25 lb. per square inch; all parts subjected to steam pressure are capable of withstanding a live steam pressure of 235 lb. per square inch. The turbine is fitted with steam and exhaust valves, a relief valve, an emergency trip governor, a hand-tripping device or knob and all the other fittings required to make it and the pump complete, and to ensure ease of working with the means for maintaining the plant in good working order.

In the vertical shaft, Figs. 5 and 8, connecting the turbine to the pump, and just below the turbine, a flexible coupling (D) with two Michell type thrust bearings (C and E) are fitted; the thrust bearings are on either side of the coupling and carry the weight of the turbine and of the pump-rotating parts respectively, whilst the flexible coupling, which is of the claw type, takes care of any slight want of alignment between the steam turbine and the pump.

The oil lubrication for the turbine and pump bearings is supplied by a rotary force pump driven by gearing (A) on the vertical shaft (see Fig. 5). It is complete with a reservoir and cooler (B), together with the necessary oil regulator and pressure gauge. The oil is circulated from the reservoir and discharged to the bearings through the oil cooler. The circulating water for the cooler is supplied from either an auxiliary sea connection or from the bilge pump. In like manner the water for lubricating the lignum vitæ guide bearings for the pump is taken from the same auxiliary sea connection or from the bilge pump.

In Fig. 1 is shown a proposed scheme for fitting the pumps in the holds of a liner, this clearly indicates the small space taken up by each unit of plant and shows that the steam turbine driving the pump may still be worked with 15 ft. of water in the holds.

We have recently had an opportunity of seeing one of the completed plants running on the test-bed at the makers' works, and of examining parts of the turbine and pump in course of construction. The pump ran very quietly and was free from vibration. The workmanship and finish are excellent, and great care has been spent in perfecting the details to render the plant reliable and ensure that the rotating parts are accurately

TURBINE-DRIVEN PIPELESS SALVAGE BILGE PUMPS.

CONSTRUCTED BY MESSRS. W. H. ALLEN, SON AND CO., LIMITED, ENGINEERS, BEDFORD.

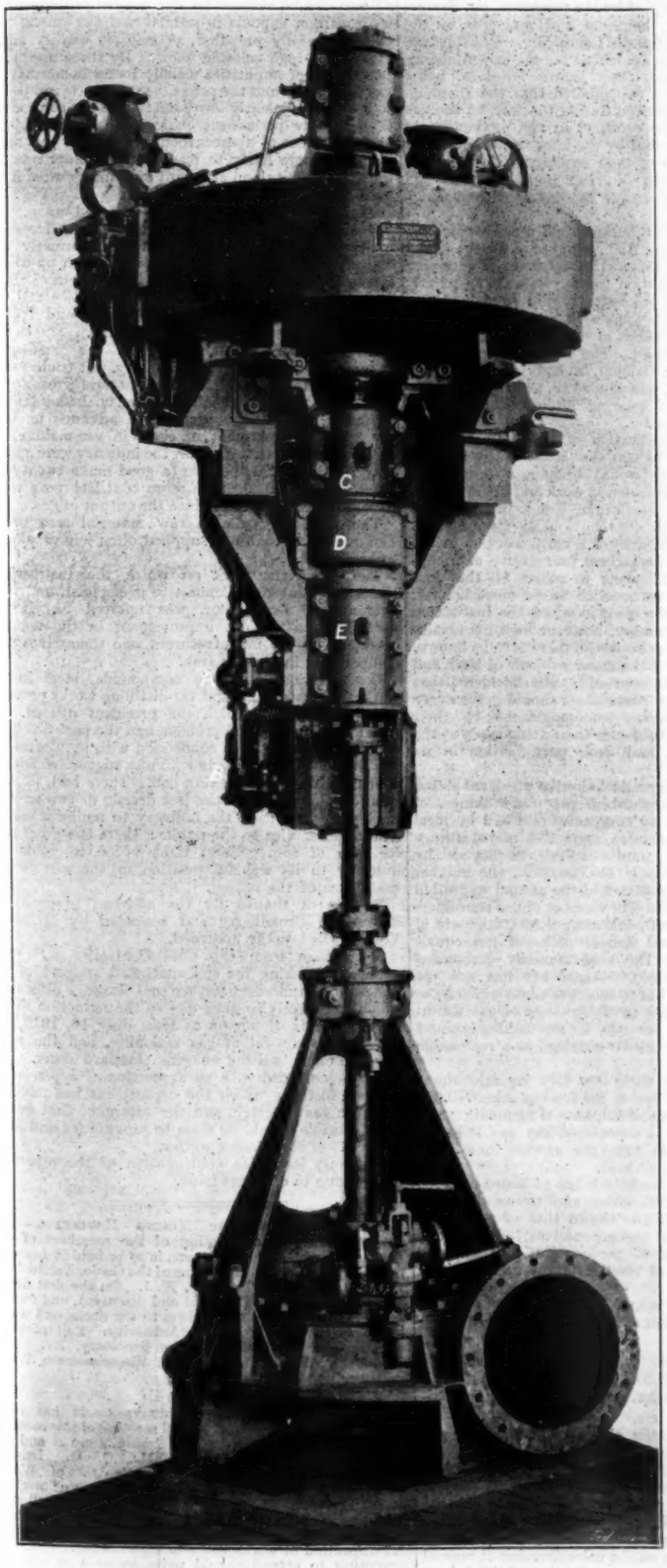
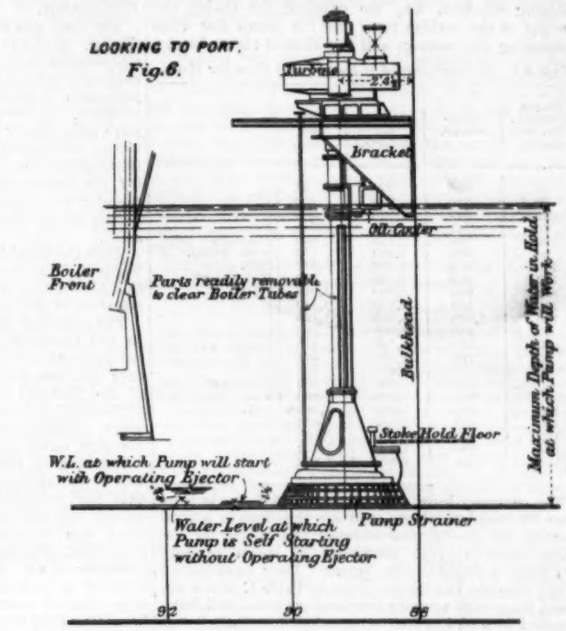
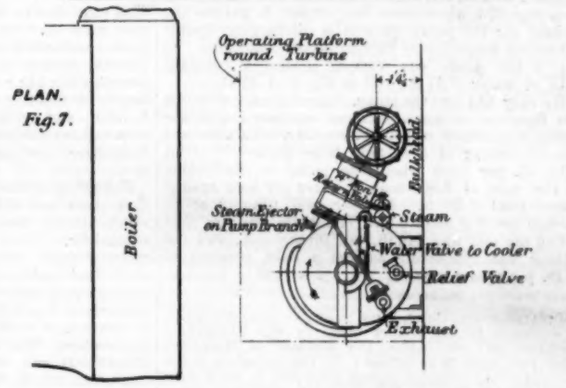
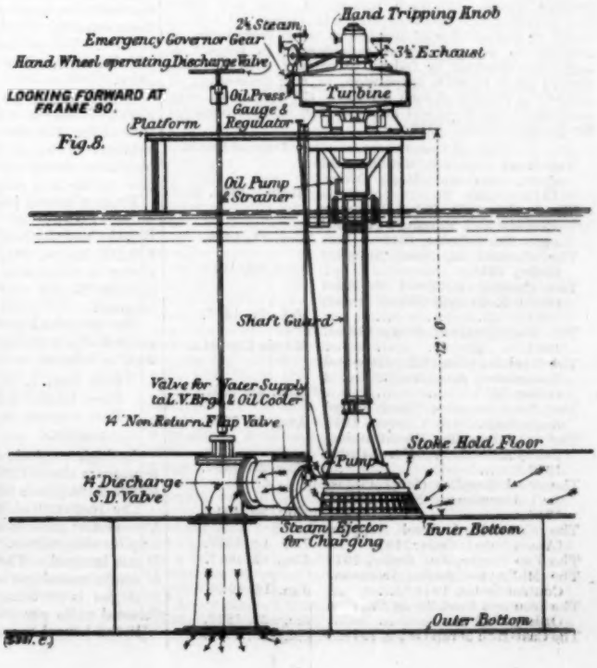


FIG. 5.







balanced. The design is such that not only may the turbine and pump be quickly opened up for examination but all the bearings and other parts are very accessible, thus enabling parts to be easily and quickly renewed in case of wear or damage; purpose-made slinging shackles, &c., are supplied for taking the weight of the turbine rotor and the pump disc when inspecting the bearings and the Michell thrust blocks.

TABLE I.—*Normal Output of Pump* 1000 *Tons per Hour.*

Steam Pressure, Lb. per Sq. In.	Revolutions.	Gallons per Minute.	Tons per Hour.	
40	590	240	64	
50	620	510	136	
60	680	1,000	268	
70	745	1,920	514	
80	790	2,420	650	Constant head, on pump, 35 ft.
90	820	2,950	790	
100	855	3,270	877	
110	915	3,690	990	
120	945	3,980	1,065	
130	955	4,150	1,110	
140	1,025	4,200	1,125	
40	600	1,000	266	
50	650	1,700	455	
60	700	2,400	644	
70	735	2,900	778	
80	790	3,380	905	Constant head on pump, 25 ft.
90	820	3,690	990	
100	885	3,980	1,065	
110	915	4,010	1,072	
120	950	4,120	1,100	
130	995	4,600	1,230	
140	1,030	4,980	1,330	

The company have, since January, 1917, made more than 70 complete plants, and are therefore in a good position to give figures showing the output of the plant under varying conditions of steam pressure and head of water on the pump. They have placed at our disposal the figures given in Table I, which are based on results actually obtained on tests, and have supplied us with the curves reproduced in Figs. 3 and 4 on page 698, which show the output in gallons per minute for the pump when it is discharging against a head of water under varying speed conditions. In Fig. 3 the pump was working against a constant head of water of 35 ft., and in Fig. 4 of 25 ft.

We may add that the steam consumption—although this figure is of small moment compared with the essential qualities of prompt starting, reliability and ease of running of a salvage bilge pump—is about 6,100 lb. per hour when the pump is discharging at the rate of 1,000 tons of water per hour against a total head of 35 ft. of water, and running at an average speed of 940 r.p.m. The steam pressure used during the test was 140 lb. per square inch, and the turbine was exhausting against a back pressure of 25 lb. per square inch.

METALLURGICAL COKE, IRON, STEEL AND IRONSTONE.—In reference to the Orders made by the Minister of Munitions set out below, the Minister of Munitions ordered on April 29 as follows: (1) The operation of the said Orders is suspended on and after May 1, 1919, until further notice. (2) Such suspension shall not affect the previous operation of the said Orders or any of them, or the validity of any action taken thereunder, or liability to any penalty or punishment in respect of any contravention or failure to comply with the said Orders prior to such suspension, or any proceeding or remedy in respect of such penalty. (3) This Order may be cited as the Steel and Iron Supplies Control (General Suspension) Order, 1919:—

Title of Order.	Date of Issue.
The Steel Supplies (Metallurgical Coke, Iron and Steel) Order, 1916	July 7, 1916.
The Steel Supplies (Steel Hexagons Rounds and Squares) Amendment No. 1 Order, 1916 ...	Oct. 31, 1916.
The Control of Steel Supplies Order, 1916	Nov. 20, 1916.
The Control of Steel Supplies (Steel Rods and Wire) Order, 1917	Feb. 24, 1917.
The Wrought-Iron Scrap Order, 1917	March 22, 1917.
The Steel Supplies (Tin plates and Ternplates) Amendment No. 2 Order, 1917	Aug. 24, 1917.
The Steel Supplies (Steel Scrap) Amendment No. 3 Order, 1917	Aug. 28, 1917.
The Steel Supplies (Metallurgical Coke) Amendment No. 4 Order 1917	Nov. 27, 1917.
The Steel Supplies (Steel Plates, &c.) Amendment No. 5 Order, 1917	Nov. 30, 1917.
The Control of Steel Supplies (Amendment) Order, 1917 ...	Dec. 14, 1917.
The Tap Cinder, &c., Order, 1917	Dec. 15, 1917.
The Midlands District Ironstone Control Order, 1918	Jan. 18, 1918.
The Iron and Steel Scrap Disposal Order, 1918	Aug. 20, 1918.
The Cast-Iron Scrap Order, 1918...	Aug. 20, 1918.

THE INSTITUTION OF GAS ENGINEERS.

THE annual general meeting of the Institution of Gas Engineers opened on Tuesday morning, the 27th inst., at the Institution of Civil Engineers, Westminster.

The chair was occupied by the president, Mr. Samuel Glover, M.Inst.C.E., engineer and manager to the Corporation of St. Helens, Lancashire. Possibly the cessation of hostilities accounted for the exceptionably numerous attendance, the lecture theatre being crowded. It must be remembered that the Members have been closely occupied during the war, at the gas works throughout the country, in the production of those substances required by the Ministry of Munitions for the manufacture of high explosives. They have thereby rendered help of vital importance to the nation which should receive the fullest acknowledgment.

After the usual formal business had been disposed of, Major H. G. L. Strange, R.E., member of the American Gas Association, was accorded a welcome, as were also members of the Institution from overseas.

The president then proceeded to deliver his address. In the introduction he made reference to the part the gas industry had taken in winning through a very long and stressful period. The recent reconstruction of the National Gas Council, a body representative of the whole industry, was alluded to, which would have every opportunity of proving its use, through the industry, to the nation.

Speaking of the Institution of Gas Engineers, he said it was apparent to him that it was early realised that gas manufacture would become a progressive science, and that co-operation in work and in developing ideas was necessary—isolation being bad for the individual, because it does not make for progress. Therefore it was decided by the early workers in the industry to exercise the highest prerogative of friendship—that of communicating to others all that had been found by each in practice to be most helpful. This continues to be the spirit in which the Institution does its work. No member, however high his attainments, professes that he knows all there is to be known. The last word on any of the many subjects of work and investigation has never been said. He considered that boards of directors and committees should grant every facility, and give every encouragement to their responsible managers to secure their attendance at the Institution meetings, and their participation in its work.

Following on with some statistics the president stated that there are 831 authorised gas undertakings, of which 519 are owned by companies and 312 by local authorities. There are also some 800 non-statutory undertakings. The total capital employed by authorised undertakings is 140,000,000*l.*, the number of employees about 100,000, and the annual wages bill upwards of 20,000,000*l.* The number of gas consumers is upwards of 8,000,000, including 4,500,000 users of slot meters. The total annual make of gas equals 250,000,000 cub. ft. The coal annually carbonised approximated to 20,000,000 tons, but has not yet reached this figure owing to improvements which have been recently developed in the process of gas manufacture. The oil used annually for gas making is about 250,000 tons, when it can be obtained at a reasonable price.

After carbonisation there are left for sale about 9,000,000 tons of solid fuel in the form of coke, 760,000 tons of tar, 170,000 tons of sulphate of ammonia; and sulphur, of which it is calculated the gas industry produces about 45,000 tons per annum in a form convertible into sulphuric acid.

From a census just recently taken of lamps used for public lighting in 1,000 cities and towns of Great Britain and Ireland, it was shown that of a total of 670,286 lamps, 585,550 are gas, and 84,736 electric—giving a proportion of 87 per cent. of gas lamps as against 13 per cent. of electric lamps used for this purpose.

The president gave some interesting figures of the gas industry's production of benzol products during the war, as follows:—

Pure benzol, 21,800,000 gallons, approximately.
Pure toluol, 8,000,000 gallons, approximately.
Pure solvent naphtha, 4,000,000 gallons, approximately.

As high explosives, the above quantity of benzol represents about 1,200,000 tons of picric acid; and the toluol corresponds to about 65,300 tons of "T.N.T."

The recovery of benzol from a normal gas reduces the specific gravity of the gas somewhat, and also the sulphur compounds. The calculated flame temperature is not lowered. The effect of the removal of 1 gallon of crude benzol per ton on the calorific value of normal coal gas is to bring about a reduction of 12 British thermal units per cubic foot.

If the benzol is used to bring up the water gas to a good standard of useful value for a general gas supply, 1,000 cub. ft. of well-made water gas of 300 British thermal units can be raised to 430 British thermal units by 0·9 gallon; and as 1 gallon of crude benzol equals about 35 cub. ft. of gas the volume would be increased by upwards of 30 cub. ft. The conservation of coal can be secured by this system of diffusing the hydrocarbon vapours in normal coal gas among other gases, carefully prepared, of suitable quality and of sufficiently high calorific value. By these means, the percentage of impurities usually found in normal coal gas is reduced, and the percentage of inserts can be kept to a quite sufficiently low point. The gas so produced is of a more permanent character than the old-time vague mixture of hydrocarbons sent out as gas, and is therefore more likely to reach the consumer retaining the same quality and standard of value as when it was tested and stored at the works.

Legislation affecting gas was touched upon. The president had gathered a summary of the Laws and Orders under which the industry has formerly been obliged to work. It showed the need of an up-to-date General Act to be incorporated in the Acts of all gas undertakings and to cover all the facilities and protection required for modern purposes and for the future development of the gas industry.

Another topic dealt with was the inadequate financial recompense of the industry. It could not be said of it that it had been profiteering during the war. Speaking of carbonization and coal conservation, to mark the distinct progressive advance made in the scientific treatment of coals in gas-making, the president stated that if to-day the industry were making only 10,000 cub. ft. per ton (a good make twenty-five years ago), 7,000,000 tons more coal last year would have been required to produce the output of gas.

The need for suitable raw material was urged. The quality of coal now supplied often left very much to be desired.

The important work on which the Institution's Refractory Materials Committee is engaged, under the guidance of Dr. Mellor, was referred to. If had resulted in a distinct improvement in the material produced by the manufacturers who themselves were co-operating in the research.

Condensation, ammonia compounds, steel in gas works, sulphate stills, and tar-distilling works provided other subjects on which the president dilated. He referred to the housing problem and the part which gas could rightly assume in connection with it. Industrial gas was touched upon, and a most suggestive address concluded with an inspiring call. There had, he said, been developed within the last decade or two an even greater desire within the industry to render a readier and larger service to the public; there is a great need for men of courage and right vision to guide the industry to its rightful position in the service and confidence of the nation.

A vote of thanks for the address, proposed by Mr. A. E. Broadberry and seconded by Mr. John Young, was heartily accorded.

A message from the Coal Controller was communicated, asking for the continued support of the Institution in meeting further coal shortage difficulties which were likely to arise due to the reduction in the working hours of miners as from July 16, 1919, the possible withdrawal of gas rationing, and the withdrawal of the existing calorific standard order. The message concluded with an expression of appreciation of the assistance which the department has received from the gas industry, and the assurance that everything possible should be done to provide for and meet the needs of the coming winter.

We must leave the continuation of the report of the meeting to our next issue.

THE INSTITUTION OF MINING ENGINEERS.—The seventy-first general meeting of the members of the Institution of Mining Engineers, is to be held in London, on June 19 and 20, in the rooms of the Geological Society, Burlington House, Piccadilly, W. 1. On the first day a number of papers will be read and discussed, and on the second day there are to be visits to the docks and warehouses of the Port of London Authority. Full information can be obtained from the Secretary, Mr. Percy Strzelecki, Albany Buildings, 39, Victoria-street, Westminster, London, S.W. 1.

BRITISH WATERWORKS ASSOCIATION.—It has been decided to hold a summer general meeting of this association at Leeds, on Thursday and Friday, June 26 and 27, 1919. The memorandum by Mr. C. G. Henzell, M.Inst.C.E., on "The National Control of Water Sources" (adjourned from the annual general meeting at Birmingham on October 6, 1918) will be read and discussed. The meeting will consider "The Joint Industrial Council for the Waterworks Undertakings Industry." An inspection of works will also be arranged. Members proposing to attend should write as soon as possible to Mr. Henzell, M.Inst.C.E., Waterworks Offices, Great George-street, Leeds, in order to book hotel rooms for one or two nights as the case may be.

INDUSTRIAL NOTES.

LORD GAINSFORD of Headlam, gave evidence at the sitting of the Coal Commission on Wednesday, the 21st inst., and stated, with reference to the scheme he outlined in the preceding day, that having ascertained the minimum wage, the cost of production and the return upon capital, the margin between that figure and the realised price would be the margin of profit divisible between the parties. The scheme was intended to give the workman for the first time a real interest in securing increased production. He was apprehensive of the competition of the United States and other areas where coal was produced, unless our production was increased and the cost reduced.

AT the sitting on Thursday, the 22nd inst., evidence was given by Mr. F. P. Rhodes, member of the Executive Council of the Mining Association of Great Britain, who said that, so far as South Yorkshire was concerned, the statement that the present system of ownership and working stands condemned was an incorrect statement. In South Yorkshire, the development that had taken place had been greater and more rapid than would have been the case under any Government Department. Further, measures for securing safety had generally been in front of, and not behind, the Home Office authority. Nationalisation would not cheapen production; it simply meant the creation of a monopoly vested in the State, and a monopoly operated by the State was a disadvantage to the community, for all monopolies had a tendency to eliminate or discourage individual effort. All monopolies possessed the power of covering up mistakes and losses by increasing prices. Unless the trade of the country could be carried on and the goods which the country produced were forthcoming at a price enabling them to be sold abroad, the nation as a whole must eventually starve.

Mr. Hugh Bramwell, who followed, said that State ownership would probably have to operate through district boards, but management should remain the same. The only way to manage a coal-mine was to appoint qualified officials, who were responsible for their actions and should not be interfered with in the discharge of their duties. If, under State ownership, he added, the surplus from the coal industry disappeared the Government would have either to tax other industries to meet the indebtedness of the mines, or to raise the price of coal to consumers.

Mr. Wallace Thorneycroft stated that the first report of the chairman and his three colleagues gave the miners preferential wages relatively to those of the rest of the community, except possibly their allies—the railway men and transport workers. In the coal industry a great deal of nonsense was talked about the disagreeable character of the work. Coal was not dirty in the true sense, but it excited, quite wrongly, many people's sympathy. The standard of health of the miner was proved to be much above the average. Mining must always be a risky operation, but it was not proved that State ownership would reduce the number of accidents. The system of private ownership and enterprise had built up the Empire, and to depart from that system as applied to the coal industry would be a national disaster. He strongly recommended the scheme of organisation as recommended by Lord Gainsford, and abstracted on page 678, *ante*.

Colonel Sir Frank Beauchamp said that in some districts the cost of wages per ton had largely increased, and unless some provision was made to meet the additional cost, there would appear to be only two alternatives, either a large reduction in the wages, or the closing down of the mines and the transference of the men elsewhere. He was opposed to nationalisation, but would prefer that alternative as a lesser evil to the nation than the closing of whole districts which were at present supplying important markets and contained large reserves of coal.

Mr. H. H. Slesser, the counsel to the Miners' Federation, gave evidence on Friday, the 23rd inst., and put forward a draft Parliamentary Bill embodying the federation's scheme for the nationalisation of mines and minerals. This would provide for the establishment of a mining council, consisting of a president, known as the Minister of Mines, and 20 members, 10 to be appointed by the King and 10 by the Miner's Federation. The members of council would be appointed for five years, and would be eligible for re-appointment. The Minister would have a salary of 2,000*l.* per annum, and he would be assisted by a Parliamentary secretary whose salary would be 1,500*l.* per annum. The scheme further provided for the taking over by the council in perpetuity of every colliery and mine and all coal, anthracite, lignite ironstone, shale, fireclay, limestone and other mineral, and all rights and easements arising out of or necessary to the working of any mines or the mining of any mineral. It provided also for the purchase of the mines; ten commissioners would be appointed to assess the purchase price, three of whom would be appointed by the Miners' Federation, and three by the Mining Association. The scheme outlined the prices to be paid, and the procedure to be followed.

Captain W. S. Saunders, secretary of the Fabian Society, then said that the administration of German State mines might be said to be a form of State capitalism. The mines were parts of the State property, used to raise revenue, the output being mainly absorbed by the State railways, the Navy, and the Army. The management was bureaucratic; the workers had no voice in the control and management of the mines. The State Governments did not recognise trade unionism; this accounted largely for the weakness of the German miners' organisations. The effect of State ownership on the conditions of life and work among the miners was in some respects good. State wages were lower than in some of the privately owned mines, but the Prussian Government provided facilities in connection with the mines superior to those at private mines; the Government, also, he added, was more generous than private owners in its treatment of cases of ill-health, in erecting miners' cottages, advancing loans to miners to build their own houses, and the establishment of baths and washhouses. In 1913 there was a net profit on the Prussian State mines of about 725,000*l.*, and in 1914 it was estimated that the surplus would reach about 850,000*l.* The production per miner in the State mines was less than in private mines, but it was not clear that the production per miner per day worked was less. Although the State mines yielded a considerable revenue, the administration was not as competent as that of the State railways. The State mines formed only a comparatively small part of the whole mining industry, while the State owned and worked practically all the railways.

The Coal Commission continued its sittings last Tuesday, 27th inst., when Mr. A. O. Hughes, head surveyor of the Powell Duffryn Steam Coal Company, said that at present, owing to the irregularities of the boundaries of the mines hundreds of thousands of tons of coal were left in useless barriers; if the coal mines were nationalised these irregularities would probably be laid out in a straight line and the loss reduced.

Mr. John Gibson, Kilmarnock, speaking on behalf of the Scottish Mine Managers' Association, stated that in regard to nationalisation, the association believed that certain national advantages might be gained by nationalisation, but so far as the nation was concerned it would not pay. He added that besides being the most difficult task to tackle, the coal industry was the most dangerous to bungle. He thought that the trade union ideal of an improved standard of life and a more equitable distribution of wealth could be best attained by a profit-sharing scheme in which every one, from the coalowner to the boy on the picking-table, was interested in the largest production of clean coal with a minimum waste of labour and material. In this way, the rich mines might be made to help to pay for the working of the poor mines. Further, the Government should tackle the distribution problem before attempting the nationalisation of production. The railways being in their hands, they could get delivery of every pound of coal immediately it reached the pit bank and distribute the coal as they thought fit. There should be standard national rates for every class of labour, from the managing director downwards; a standard rate of interest on capital; a division of profits; the cost of new plant should be taken out of revenue.

Mr. W. Blane, mining engineer, stated that after four years' experience as a responsible Government official he had come to the conclusion that if the coal industry were to be run by a Government Department on lines similar to those on which existing departments were run, it would be a failure commercially. The principal cause of inefficiency in Government Departments was excessive centralisation. The greatest evil was perhaps the control exercised by the Treasury over expenditure, appointments and promotions; this fostered inefficiency, delay and financial loss, any one of which would be fatal in a large industrial undertaking.

A correspondent to *The Times* gives the following figures of output of coal in tons per person employed at the collieries for the years from 1910 down to last year: 1910, 252 tons; in 1911, 255; in 1912, 239; in 1913, 255; in 1914, 251; in 1915, 265; in 1916, 257; in 1917, 243; and in 1918, 226 tons. It will be seen, therefore, the correspondent adds, that the output per person employed reached its highest in 1915, when the man-power of the collieries was at its lowest owing to recruitment for the Services. The patriotic impulse was then at its strongest. The total output in 1918 was 227,714,579 tons. On the basis of the output for the first three months of the current year, the total output for 1919 would be about 224,000,000 tons, notwithstanding that there were nearly 100,000 more men in the mines in March last than in 1918. The average output per man for the present year on the basis of the figure for last March would be only 203 tons.

Speaking last Monday at the seventeenth annual general meeting of Messrs. William Beardmore and Co., Limited, Sir William Beardmore, Bart., chairman and managing director, said that in 1914, just before the war broke out, the total number of employees in the firm was 11,080, and that when the armistice was declared in November last the number had risen to 42,500. The weekly wages paid in 1914 averaged 22,800*l.*; in 1918 this weekly wage figure had reached 145,000*l.* The total sum paid in wages during the war period was only a few thousand pounds short of 18,500,000*l.*

The total turnover of the firm during the period of the war was approximately 68,275,000*l.*

THALLIUM EXTRACTION FROM PYRITES FLUE DUST.—With the object of utilising waste products, Messrs. G. Sisson and J. S. Edmonson tried to extract selenium from the flue dust of the sulphuric acid plant of the Blaydon Chemical Works. They failed so far as selenium is concerned, but they found some thallium. The flues in question serve for conducting the sulphur gases from the pyrites kiln to the Glover towers, and have to be cleaned periodically. The kilns are charged with copper pyrites from Spain, which contain, in addition to about 2 per cent. of copper, a large number of other elements. The more volatile of these, arsenic and selenium, pass with the sulphur beyond the flue into the Glover tower. In the flues collect dust of iron oxide, small quantities of lead and copper, and volatile products condensed at about 450 deg. C., such as antimony, bismuth, thallium, &c. Thallium is not a rare element, but it occurs, always in small quantities, associated with other metallic sulphides, in various ores. It is not found in all pyrites, and though the sulphuric acid dust may contain up to 8 per cent. of thallium, the percentage rarely exceeds 0·25. That was the amount found at the Blaydon Works (Journal of the Society of Chemical Industry, March 31, 1919) in the 15 cwt. of dust which had accumulated during six months in which 1,500 tons of pyrites had been burnt. The total yield was only 4 lb. of thallium. The extraction depends upon the solubility of thallium in sulphuric acid (the dust is extracted with the hot acid) and the sparing solubility of the thallium chloride into which the sulphate is converted.

EXPLOSION OF STEEL CYLINDERS FOR COMPRESSED GASES.—Two recent cases of explosions of steel cylinders, while being charged, the one with hydrogen, the other with oxygen, are discussed at some length by W. Hempel, of Hanover, in the *Zeitschrift des Vereines Deutscher Ingenieure*, of March 8, 1919, pages 205 to 212. The conclusion arrived at in both cases is that explosive gas mixtures were not responsible for the accident, but that the steel gave way for reasons more or less cleared up. The hydrogen cylinder burst while being charged with electrolytic hydrogen from a compressor when the gauge registered 140 atmospheres; the full pressure was to be 150 atmospheres. The head and shell of the seamless cylinder remained perfectly intact, but a hole was blown through the spherical bottom and 75 cm. deep into the floor on which the cylinder was standing. The cylinder was hurled through the roof of the building and buried itself into the earth, 85 m. away; the compressor was not damaged. Two men were badly burnt. The mechanical, metallurgical and chemical tests of the head and shell of the seamless tube (9 mm. wall thickness) fully satisfied the regulations; the steel composition was: 0·49 carbon, 1 manganese, 0·38 silicon, 0·032 sulphur and 0·026 phosphorus. The composition of the bottom varied very slightly from these figures, but there were segregations and local accumulations of sulphur. The bottom was cleft like a gaping mouth; half of the steel remained in position and whole, the other half was blown away and cracked. A fold seemed to have been formed near the centre of the bottom on the inside from which a crack started; internal illumination of the bottom, practised in the case of shells, would probably have disclosed the fold or crack. The second bottle was being charged with oxygen from liquid air when the cylinder was blown to pieces while the gauge indicated between 80 atmospheres and 100 atmospheres. Nobody was hurt, because the cylinder was standing behind a strong brick wall, and 18 of the many fragments were recovered. In this case the various tests concordantly showed the material not to have been up to the standard. The composition was: 0·64 carbon, 0·97 manganese, 0·38 silicon, 0·032 sulphur and 0·033 phosphorus. The steel was imperfectly annealed and not sufficiently tough; the strength was found high, the elongation low throughout; the disposition of the cracks and lines of fracture was in accordance with the assumption of a brittle material. The wall thickness fluctuated moreover between 6·8 mm. and 10·8 mm. Hempel suggests that some crack had been formed previously, possibly by a fall of the cylinder, and that, as in the first case, it was not necessary to assume a real gas explosion as immediate cause of the accident. One crack had evidently started from one of the letters by which the finished cylinder had been marked. The article is illustrated by four pages of photographs.

A NEW TYPE OF RECUPERATIVE FURNACE.*

By WALTER ROSENHAIN, B.A., D.Sc., F.R.S., and E. A. COAD-PRYOR, B.A.

IN connection with the research work on glass and refractories which has been carried on at the National Physical Laboratory for the past four years, the necessity was early felt for a new type of experimental furnace suitable for glass meltings and for the firing and testing of refractories at very high temperatures, maintained for a considerable time. None of the available types of furnace appeared to meet the requirements of this work, particularly because it was regarded as essential that the furnace should be capable of running for long periods entirely without attention, so as to avoid the necessity for a "night shift" for experimental work.

Among furnaces capable of melting down cones 28 to 30, or of attaining temperatures above 1,600 deg. C., there was only a very small choice. Most of these worked with an air blast derived from a fan or blower, and such a plant could not be left to run unattended over night. It thus became evident that a gas or oil-fired furnace, working with a natural draught, was the only suitable type, and with a furnace of that kind the very high temperatures desired could only be attained by some method of preheating the air supply. The choice lay between the types generally known as "regenerative" and "recuperative." The regenerative type was at once ruled out on account of the necessity of reversing the valves at frequent (usually half-hourly) intervals, an operation which would require the presence of an attendant throughout the run. On the other hand, existing furnaces of the recuperative type, of which the well-known "Hermannsen" furnace is a good example, did not appear to be relatively adaptable for use in small sizes, owing to the relatively large dimensions of the recuperator blocks and the thickness of the walls of the passages through which the interchange of heat takes place.

The authors were accordingly led to design a special type of furnace for their work and, as a result of several successive modifications, they have now arrived at one which is not only eminently successful and satisfactory for their special purpose, but appears to lend itself to development for many other uses, including its adaptation both to much larger and to smaller sizes than those which they have hitherto constructed.

In seeking to design a furnace capable of yielding very high temperatures, the authors considered that the principal factor must lie in the design and construction of the recuperator or preheater in order that the waste heat of the outgoing products of combustion should be transferred as efficiently as possible to the incoming gas (since coal gas was, for reasons of convenience, adopted as the fuel to be used, preheating of the gas was not contemplated). The type of recuperator or preheater adopted, therefore, determined the entire design of the furnace. The only form of recuperator which gave promise of affording the desired efficiency appeared to be that consisting of a nest or battery of tubes through which the incoming air is drawn, while the products of combustion circulate about the interior of the tubes. This type is, of course, well known in such devices as steam boilers, condensers, &c.

The initial and perhaps the principal difficulty in the construction of a recuperator of the tubular type, especially when very high temperatures are to be attained, lies in finding a suitable refractory material of which the tubes can be made. In the authors' earlier experiments a considerable degree of reliance was placed upon the cooling effect of the incoming air, but experience very quickly proved that this did not suffice to protect tubes of insufficiently refractory material. Sets of tubes made of vitreous silica, of the best fireclay, and of "Salamander," rapidly failed in succession, either by breakage or "sagging." Fortunately the authors' research work, dealing with "special" refractories, had already drawn their attention to the remarkable properties of bodies made of silicon carbide made up with various contents of china clay, or good fireclay serving as binder. Tubes made of this material have proved eminently satisfactory, and the initial difficulties of making the tubes have been overcome.

The composition of the tubes has varied somewhat, a larger percentage of clay being permissible in those tubes intended for use in the cooler parts of the recuperator than in those exposed to the products of combustion leaving the combustion space at the full furnace temperature. For the latter position, where the tubes may attain a very high temperature (between 1,400 deg. C. and 1,500 deg. C.) a mixture containing about 20 per cent. of china clay and 80 per cent. of silicon carbide has been found quite satisfactory, although successful tubes have been made with china clay up to 40 per cent. The higher percentages of china clay only become desirable, however, if the tubes are to be made by a slip-casting process, for which purpose the 40 per cent. china clay mixture is very suitable. Care must, however, be taken to see that a china clay of the most refractory kind is used and that it is not in any way contaminated with foreign fluxes of any sort, as a slight decrease in the viscosity of the binder at high temperatures allows the tubes gradually to sag and fail in service. For the tubes to be used for the colder ends of the recuperators the proportion of silicon carbide may be progressively reduced. The tubes can be prepared by slip-casting, moulding or extrusion in any of the well-known ways; if the percentage of china clay is very low the "green" tubes are very fragile, but they become very strong and hard after firing. The tubes are fired up to a temperature of fully 1,500 deg. C., i.e., a temperature higher than that at which they are to be used. This is important, because articles made of silicon carbide exhibit a great tendency to sag or deform (i.e., have a low viscosity) the first time that they are raised to a given temperature. During the firing they must, therefore, be carefully supported, and they must not be used at a higher temperature than that to which they have been initially fired.

The design of the furnace now employed by the authors is the result of a development which has taken place in several steps, and it may be interesting to trace these very briefly.

To indicate the general size of the furnaces to be described, it may be stated that in the first furnace designed for glass-melting experiments the combustion space, intended to accommodate one pot or crucible, was approximately cylindrical, with a diameter of 24 in. and a height (inside) of 18 in., with a total volume of 4·8 cub. ft. and an internal surface of 16 sq. ft. The general arrangement of this furnace is indicated in the diagram, Fig. 1, which shows a horizontal section. The recuperator contained 14 tubes each 4 ft. long and 1¼ in. in diameter.

It will be seen that in this furnace the tubes were comparatively few in number and of large diameter, while the products of combustion, passing outwards from the furnace to the chimney, take an uninterrupted course direct from the combustion chamber to the outlet flue, i.e., from points A to B in the horizontal section, Fig. 1. The result of this arrangement proved to be that the heating surface provided by the recuperator was altogether inadequate, and that, in consequence, the incoming air was not sufficiently heated, while the products of combustion remained too hot and caused undue heating in the chimney. These disadvantages were, to a considerable extent, overcome in the next modification in the furnace, the arrangement of which is indicated, again in horizontal section, in Fig. 2. The number of the tubes has been increased to 20, and the recuperator lengthened by 13 in., the diameter of the tubes remaining the same as before.

The course of the products of combustion through the recuperator, however, has now been controlled by the introduction of four baffles, forcing the gases to follow a zig-zag and, consequently, much longer path from the combustion chamber exit to the outlet flue. In this form the furnace gave very satisfactory service, temperatures of 1,550 deg. C. being obtained with ease in the melting chamber, and a large number of experimental glass meltings have been carried out in it. The furnace could be allowed to run for many hours without any attention whatever, and, provided that the gas pressure and draught remained constant, a very steady temperature was maintained. After a little experience it was possible to set the controls in such a way that the furnace would attain within 50 deg. of the desired temperature in a desired time; such an adjustment could be made in the evening and the furnace found at the desired temperature in the morning.

The general arrangement of this furnace, apart from the recuperator—which has already been described in detail—will be readily understood from Fig. 2. It will be seen that the preheated air leaving the tubes passes into a collecting chamber (C), and is then directed by a series of baffles (D) into a mixing chamber (E).

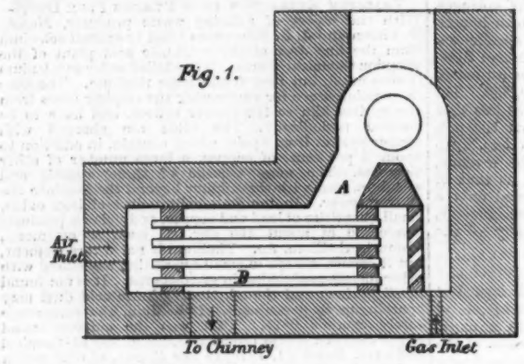


Fig. 1.

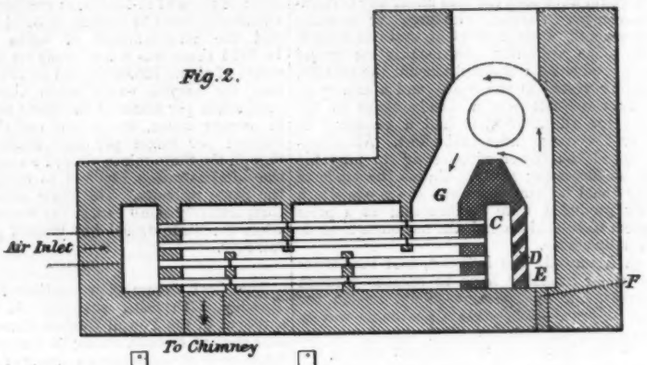


Fig. 2.

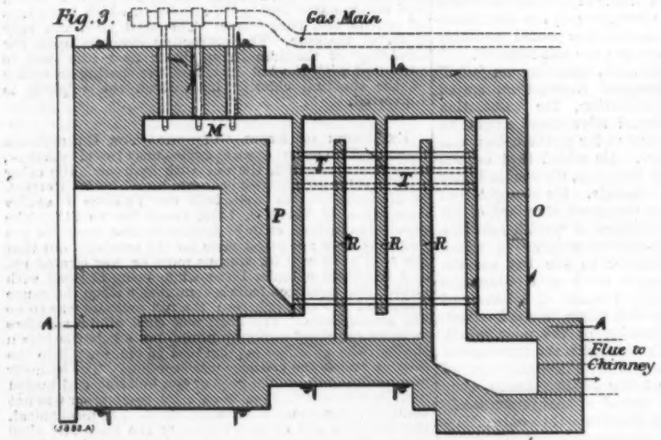


Fig. 3.

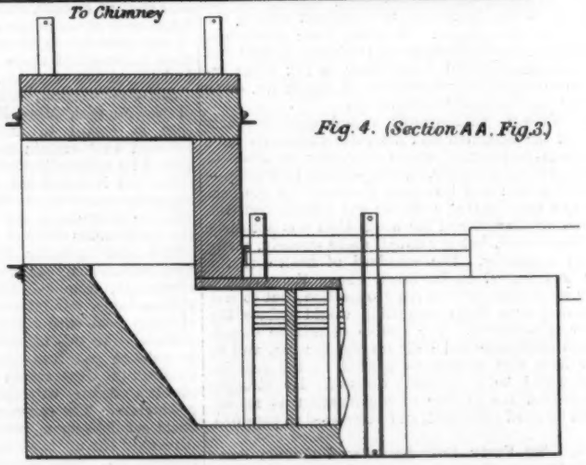


Fig. 4. (Section A A, Fig. 3.)

* Paper read before the Ceramic Society at Middlesbrough, on Thursday, May 22, 1919.

Here it meets the coal gas, which enters by three horizontal tubes or burners (F), the flame is developed in chamber (E) and in the space around the pot in the combustion chamber, and passes out through the exit (G) into the recuperator.

This particular furnace was provided with an opening at the front, through which the pots could be inserted or removed, and a working opening in the roof for manipulating the glass or other contents of the pot.

In the subsequent development of the furnace further changes have been made in the same general direction. These have resulted in the construction now adopted, in which the recuperator tubes are much more numerous and of smaller diameter and of much smaller thickness of wall, while the system of causing the products of combustion to take a zig-zag path by means of baffles has been developed to a much greater extent.

A most successful furnace of this type has been constructed for the purpose of experimental firing and testing of refractories at high temperatures. The working chamber of this furnace has a floor area of 2 ft. 9 in. wide by 1 ft. 6 in. deep, having an arched roof with a minimum of 20 in., thus giving a total volume of 10 cub. ft. The flame passes across this space horizontally and a very uniform heat is produced, the variation from the inlet end to the exit end being of the order of 20 deg. at temperatures in the neighbourhood of 1,500 deg. C. Temperatures as high as 1,650 deg. C. have been attained.

The general arrangement of this furnace is shown by means of two sections, in Figs. 3 and 4. Fig. 3 is a horizontal section through the recuperator and mixing chamber, while Fig. 4 shows a part sectional elevation representing a section along the line, AA, Fig. 3.

It will be seen from the horizontal section, Fig. 3, that the air entering at (O) passes through the tubes (T) into a collecting chamber (P), and thence into the mixing chamber (M). Here it meets the coal gas which enters through three horizontal tubes. From this chamber, where the flame is formed, the flame ascends vertically into the combustion of furnace chamber proper, which is placed at a higher level than the recuperator. After passing across the combustion chamber the hot gases descend and pass through the recuperator, being forced to take a long zig-zag course by the three baffles (R). A general view of this furnace as seen from the front, with the combustion chamber open, is shown in Fig. 5. The recuperator, which lies at the back of the furnace, is not seen in this photograph. The arrangement of the tubes and the general construction of the recuperator itself is best seen from the photographs, Figs. 6 and 7. It will be seen that the tubes are built up in 8-in. lengths and that the joints are supported in the baffles, these baffles being themselves built up of special shaped firebricks, the shape of the individual pieces being clearly indicated in the photograph, Fig. 7 The recuperator contains nine courses of tubes, each course consisting of 13 tubes, each tube being made up of four 8-in. lengths.

Perhaps the greatest difficulty which has had to be overcome in the construction of a furnace of this type is the prevention of cracking and breakage of the tubes as the result of thermal expansion, shrinkage or other movements occurring in the furnace and the baffles. The first effort to secure this was made by endeavouring to leave the tubes as lightly held as possible in the apertures of the baffle blocks. This, however, did not prove entirely successful, and, in course of time, the furnace suffered from the gradual destruction of the tubes owing to various movements occurring in the baffles. The device finally adopted has been to avoid attaching the baffles to any part of the furnace in any rigid manner. Where they stand on the floor of the recuperator chamber they are placed on a layer of dry grog of a refractory clay which does not become hot enough to adhere to the baffle blocks. This leaves the baffles free to expand equally in all directions. Anchorage to walls at the sides is also avoided by building the baffles loose and dry into slots formed in the side walls. The amount of leakage through crevices in these slots is very small, as the resistance to the passage of the gases is much greater through these small interstices than around the comparatively open paths which the gases are intended to follow.

So far as experience has yet gone this device promises to solve the difficulty to a very considerable extent and has certainly lessened the breakage of tubes very much. Even without this special device, however, the furnace, from which the illustrations in Figs 3 to 7 are taken, has successfully withstood 62 heats, in many of which extreme temperatures have been attained. The furnace is still working, but the gradual breakage of tubes, due to the causes indicated above, has somewhat impaired its efficiency.

A second furnace on slightly different lines, again intended for melting purposes, has been constructed quite recently, the improvements in the recuperator construction indicated above having been applied to it with considerable success. A general photograph of this furnace is shown in Fig. 8, in which the recuperator is seen with its covering removed. An interesting feature in the case of this furnace is the provision made for the working opening in the crown of the melting chamber. This has been provided by means of a large circular aperture 14 in. in diameter, in a solid block made of silicon-carbide, measuring, in all, 22 in. by 18 in. by 9 in. This block has been built of wedge shape to fit in to the construction of the arch, and is proving eminently satisfactory under the somewhat difficult conditions which it is called upon to resist.

In connection with these furnaces, in which, as has already been indicated, very high temperatures are reached, some interesting experiences in regard to furnace linings and materials have been obtained. In the first furnace the lining of the combustion chamber was made of magnesite brick. This proved entirely unsatisfactory, as the brick failed very rapidly in consequence of "spalling." No doubt this was due to insufficient firing of the magnesite during manufacture. The magnesite lining was then replaced by one of crude zirconia bricks. These proved eminently successful from the point of view of heat conservation, the gas consumption of the furnace for a standard working temperature of 1,500 deg. C. being decreased from 1,200 cub. ft. per hour to 720 cub. ft. per hour. A marked diminution in the temperature of the external walls of the furnace in the neighbourhood of the combustion chamber was also clearly evident. This lining lasted rather longer than that of magnesite but failed through much the same cause, viz.: "spalling." Here again the manufacture of the brick was doubtless at fault. The evidence obtained shows clearly that if a zirconia brick of satisfactory quality can be produced it would materially increase the economy of gas-heated furnaces.

In the furnace illustrated in Figs. 3 to 7, the whole of the combustion chamber has been constructed of a good quality firebrick, but it has been protected by a wash of silicon-carbide made by mixing the powdered carbide with 5 per cent. of china clay, in the form of a slip, and applying this with a brush. In spite of the very high temperature which this furnace has frequently reached, the walls and roof of the combustion chamber, and of the passages leading to and from it, are quite sound after 62 heats. It is, however, necessary, in order to attain this result, to renew the wash of silicon-carbide at comparatively frequent intervals, as, for instance, after five or six heats. If this is not done, the coating of carbide flakes off, the brick is exposed and the advantage of the carbide coating is lost. For furnaces which are heated intermittently, so that access for repainting is possible, the use of the silicon-carbide wash appears to offer important advantages; in furnaces where the heat is long continued this advantage may not be so great; even then, however, the possibility may be considered of applying the carbide in powdered form while the furnace is hot and the surfaces may be sufficiently soft to allow the carbide to adhere.

The draught used for the working of these furnaces is obtained from comparatively small chimneys, the stacks in both cases being less than 35 ft. in height. This draught is found sufficient so long as the furnace is in good condition; sometimes, however, it has been found desirable to accelerate the heating of the furnace, or to attain an exceptionally high temperature, by the application of a forced draught. This has been done

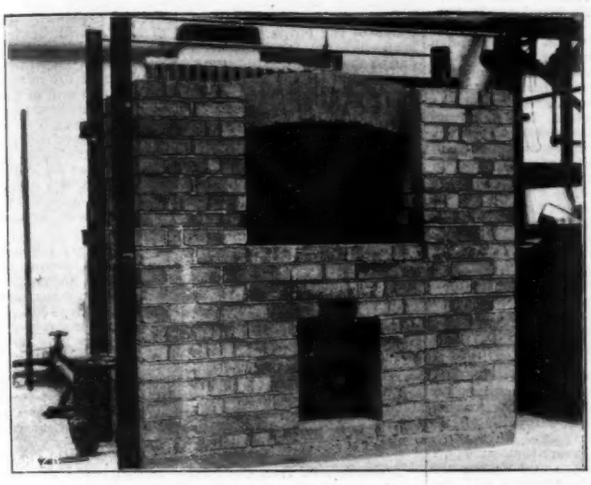


FIG. 5.

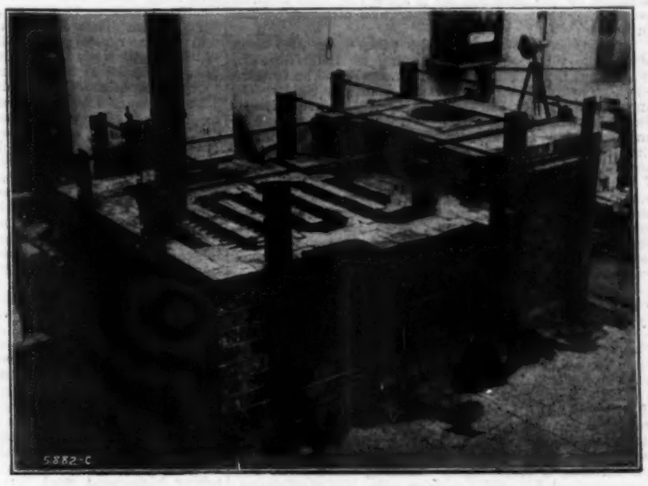


FIG. 8.

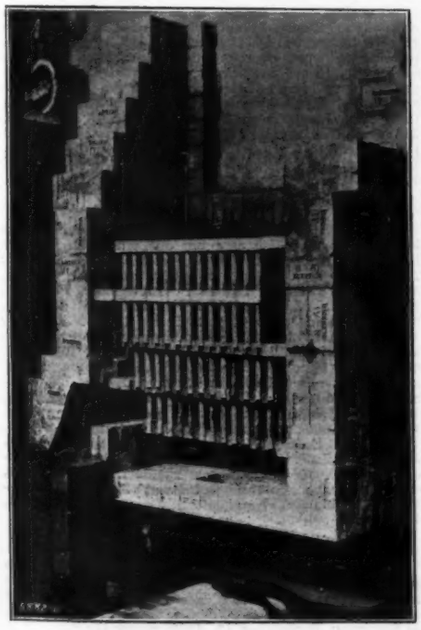


FIG. 6.

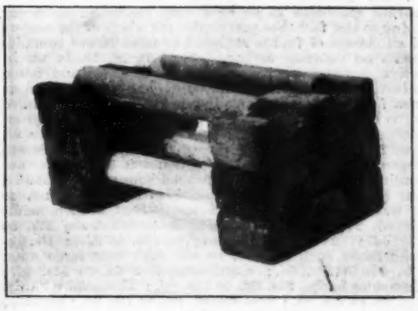


FIG. 7.

by connecting the air inlet of the furnace to a low pressure air supply derived from a fan. This expedient has, however, only been resorted to in quite exceptional circumstances, and the data given as regards gas consumption and temperatures refer to the use of the furnace with natural draught alone.

Some data as to the gas consumption and temperatures attained in various parts of the furnace may be of interest.

In the case of the kiln furnace described in reference to Figs. 3 to 7, the gas consumption, running at a temperature of 1,500 deg. C., is 600 cub. ft. per hour of town gas of, approximately, 500 B.T.U. The air temperature, where the air leaves the recuperator, is between 250 deg. C. and 300 deg. C. below that of the working chamber of the furnace, so that the highest temperature attained by the incoming air is always by that amount lower than the maximum temperature attained by the furnace.

Temperatures attained by the tubes have also been observed. With a furnace running at 1,400 deg. C., it is found that the row of tubes nearest to the furnace chamber attain 1,200 deg. C., the second row 900 deg. C., and the third row 650 deg. C. It will be seen, therefore, that the material of the tubes is not exposed to any excessive temperature, but, on the other hand, the fact that these tubes of comparatively small diameter and thickness are required to bridge a distance of about 7 in. makes it very important that they should have ample power to resist any tendency to flow or sag, and it is probably for that reason that the use of silicon-carbide has been found to be necessary. At the temperatures at which they are called upon to work in these recuperators there is no serious deterioration from oxidation.

It will be readily understood that the very efficient working of a furnace of this type can only be attained by combining with the efficient recuperation which this system affords an accurate control of gas and air supply. The authors have found it useful for this purpose to use a recording instrument giving a record of the carbon dioxide content of the flue gases, as this has provided a most certain means of securing a proper adjustment of gas and air. This being the case, it will be seen that the atmosphere in the furnace when working at fullest efficiency will be very slightly oxidising. If a larger excess of air is either drawn into or blown through the furnace, a more highly oxidising atmosphere can be maintained, but with a corresponding loss of efficiency, so that the furnace will not attain its full temperature. On the other hand, a slight restriction of the air supply will readily produce a reducing atmosphere, which, in this case, is accompanied by a much smaller loss of efficiency.

The authors desire to express their indebtedness to Sir Richard T. Glazebrook, C.B., F.R.S., for his interest in their work.

REMOVING PLUGS FROM STOP COCKS.—A plug sticking in a stop-cock is very awkward to deal with, and attempts to remove it not rarely result in breakage of the plug. A simple device which has proved useful in many cases has been adopted in the Pittsburgh Laboratory of the United States Bureau of Mines, and is described in the April issue of the Journal of Industrial and Chemical Engineering by Vernon C. Allison. It is simply a slab of hard wood, maple or *lignum vitæ*, into which a number of recesses have been cut of such shapes as to fit the ordinary sizes of plugs. Each recess consists of a slit, to be slipped over the neck of the plug, widening out inside into a circular hole to take the winged end of the plug. When hand pressure is not sufficient for withdrawing the plug, the little device can be used in combination with a V-clamp or a vice. Allison mentions that he removed seven stop-cocks in four minutes, and that he has had no accidents so far.

THE BRITISH FEDERATION OF IRON, STEEL, TINPLATE AND METAL MERCHANTS (INCORPORATED).—Sir Johnstone Wallace, the chairman of the above federation, presided at a meeting of the Executive Council held last week at the London Chamber of Commerce. With a view to co-ordinating the policy of the federation, and providing a definite programme upon which the future working of the organisation will be based, a scheme embodying fourteen points was drawn up by the Executive Council of the federation and approved. Among these points, we may mention, very briefly, the following:—To get the fullest possible recognition in official, manufacturing and labour circles of the indispensability of the merchant to export, import and home trade of the country; To endeavour to get manufacturers to work in harmony with the federation, which will use its best efforts to convince them of the advantages of trading through merchants, whether in home or foreign markets; To discourage any movement on the part of bankers to take up merchant trading. Some German banks took advantage of the information obtained through their fiduciary position, to do this; To oppose the imposition of any unfair rates of freight, such as those notable cases obtaining in pre-war years, whereby British ships carried German made goods in the same ships at about 50 per cent. less rate of freight from certain Continental ports than from British ports; To watch railway and other transit rates and conditions in particular with regard to seaborne and continental through rates, and guard against unfair treatment of traders' interests therein; To endeavour to secure the improvement of transport facilities which will tend to extension of British trade. The new offices of the federation are at 11, Queen Victoria-street, E.C., where members and others interested can obtain full information.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The total of orders received is improving, and business appears gradually to be reverting to normal conditions, but the forward movement is hampered by the continued uncertainty of pig-iron prices, coupled with delays in railway transport. It was anticipated that the revised rates of common and finished irons would hold good at least for a month, and that manufacturers would have a certain established basis to work on; but changes are being effected weekly, and, almost without exception, these are in an upward direction. West Coast hematites are quoted at 9*l.* 10*s.*, whilst East Coast makers have advanced quotations for local delivery to close upon this figure. Both foundry and forge irons show further advances. Lincolnshire foundry stands at 7*l.* 12*s.* 6*d.*, Lincolnshire forge 7*l.* 10*s.*, Lincolnshire basic 8*l.* 5*s.* to 8*l.* 7*s.* 6*d.* Derbyshire makers are quoting basic 8*l.* 5*s.* to 8*l.* 10*s.*, foundry 7*l.* 10*s.*, and forge 7*l.* 7*s.* 6*d.* Bars are unchanged at 22*l.*, and sheets at 25*l.* Billet makers have been obliged to regulate prices accordingly to cover increased costs, Thus the margin between local material and that offered by American makers continues to widen. It is rumoured that certain steel makers have taken advantage of the lower-rated offer, and have placed orders with American producers to cover some of their contract commitments. The new import figures will show whether this report is true. Local billet makers are quoting 17*l.* 2*s.* 6*d.* for Siemens acid, Bessemer acid 16*l.* 12*s.* 6*d.*, hard basic 15*l.*, soft basic 14*l.* 10*s.* In the heavy branches, despite the drawbacks indicated, business shows a satisfactory increase. Mills and foundries have a lot of work on hand which they will be better able to cope with when more iron furnaces are put into blast. Constructional work abroad, and the requirements of the British and Indian railways are responsible for sustained activity in the railway material departments. Shipbuilding requirements, which have been growing weekly, are reaching abnormal proportions. Apart from home needs, Japan, Spain and Italy are buying freely, and substantial contracts are in course of completion on Colonial account, principally for Australia. Engineers' tools are in heavy demand from the shipyards, while business in agricultural implement parts, wire, rope, saws, files and gardening requisites is more than sufficient to warrant full-time working. America and France are taking high-speed steel, but this department and the electric and crucible steel shops form the least active section of the South Yorkshire steel industry.

South Yorkshire Coal Trade.—Business in the open market continues to be of a very restricted character owing to the fact that practically the whole of the output of all classes of fuel is required to meet larger commitments on contract account. Best steam hards are in active demand for railways, blast furnaces and home industries generally. A limited quantity is going coastwise for shipment. Many inquiries from neutrals have to be turned away owing to the continued embargo on the traffic *via* Hull. Cobbles, nuts and slacks are all firmly held at maximum rates. Cokes are in moderate request. Conditions in the house-coal section are considerably easier. An improved tonnage is available, but requirements have dwindled with the continuance of warmer weather. Quotations:—Best branch hand-picked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

THE BRITISH ENGINEERS' ASSOCIATION.—The annual general meeting of this Association will be held on Tuesday, June 3, at the Connaught Rooms, at 11.45 a.m., and will be followed by a luncheon at 1.15 p.m.

NAVAL HONOURS.—The following honours have, with the approval of H.M. The King, been conferred upon naval engineers, among others. For valuable services in connection with the war—To be O.B.E. (Military Division), Engineer-Commanders T. A. Graham, R.N.R., and G. W. Todd, R.N.R.; Engineer-Lieutenant Commander J. Young, R.D., R.N.R.; and Engineer-Lieutenant R. Driscoll, R.N. To be M.B.E. (Military Division): Artificer-Engineer W. H. Robbins, R.N. For services in action with enemy submarines—To receive the Distinguished Service Medal, Engineman C. E. Dixon, R.N.R. For services in the auxiliary patrol—To receive the Meritorious Service Medal, Engineman A. G. B. Harper, R.N.R., J. W. Moore, R.N.R., J. H. Penny, R.N.R., and H. Stead, R.N.R.; Mentioned in Despatches, Engineman E. Kenny, R.N.R., and T. B. Murt, R.N.R. Services in mine-sweeping operations—Mentioned in Despatches, Chief Engineman W. N. Ruddiman, R.N.R. For Miscellaneous services—To receive the Distinguished Service Order, Engineer-Lieutenant-Commander P. L. Butt, R.N.; Mentioned in Despatches, Engineman F. Baker, R.N.R., Engine-room Artificer R. M. Milburn. For services in the Mercantile Marine—Commended for Services, Chief Engineers E. F. Fleuriot and A. Thomson. The President of the French Republic has conferred the "Croix de Guerre" upon Engineer-Lieutenant-Commander E. F. Briggs, D.S.O., R.N. H.M. the King of the Hellenes has conferred an Officership of the Order of George I upon Engineer-Lieutenant-Commander G. Cocks, R.N., while H.M. the King of Serbia has bestowed the Gold Medal for Military Valour upon Engine-Room Artificer H. J. S. Smith, R.N.R., and the Gold Medal for Zealous Service upon Engine-room Artificers T. Johnson and V. F. Williamson.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Cleveland pig-iron market keeps firm and fairly active. This week interest centres in the announcement that the ironmasters have agreed to regard existing pig-iron quotations as maximum prices. The action is generally approved of, and has promoted a pronounced opinion that it will very materially assist a steady flow of genuine trade. The feeling of uncertainty has been removed, and prospects much brightened. Many complaints are again heard of inconvenience due to scarcity of trucks, and the Board of Trade has once more been appealed to on the matter in the hope that they will be able to provide means of facilitating distribution. Cleveland foundry iron is hardly purchaseable for early delivery, practically the whole of the output to the end of next month having been sold, but forge quality is comparatively plentiful, due to the continued abnormal output of that description of iron. Transactions now being put through are mostly over the third quarter, but contracts to the end of the year are also being arranged. For home consumption, both No. 3 Cleveland pig-iron and No. 4 foundry are 160*s.*, and that is also the maximum quotation for No. 4 forge, which quality, however, is obtainable at 158*s.*, and No. 1 is 164*s.* The export rates are 5*s.* above the foregoing quotations, but foreign trade is very quiet, for not only are export licences difficult to secure, but producers are reluctant to sell for shipment abroad with present home needs so urgent.

Hematite Iron.—The stringency is in no way relieved in the East Coast hematite branch. Iron cannot be purchased at all on early accounts, and very few makers are disposed to commit themselves ahead as they are already well sold forward. Nothing below 190*s.* is named for Nos. 1, 2 and 3, and 192*s.* 6*d.* for No. 1 for home use; whilst for export the former are 195*s.* and the latter is 197*s.* 6*d.*

Coke.—Though a more than ample supply meets the rather heavy demand for coke, values are well maintained. Medium blast-furnace kind is 39*s.* at the ovens, and quality low in phosphorus 41*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—Little news of moment is ascertainable concerning finished iron and steel. Good inquiries from abroad are reported, and in the home trade shipbuilding requisites and railway material are in most demand. Manufacturers appear to be experiencing most trouble in maintaining production owing to labour difficulties. Week-end repairs are greatly hampered by the action of the engineers in refusing to work overtime until a 44-hours' week is conceded. Prices are firm. Steel plates for export are 18*l.* f.o.b., and to home customers the following are among the principal market quotations:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.* 5*s.*; strip iron, 21*l.* 5*s.*; ship rivets, 27*l.* 5*s.*; steel ship, bridge and tank plates, 17*l.*; steel angles, 16*l.* 10*s.*; steel joists 16*l.* 10*s.*; steel hoops, 23*l.* 5*s.*; and heavy sections of steel rails, 15*l.*

PUBLIC WORKS.—The works for which sanction has been obtained or for carrying out which applications have been made comprise the following:—*Electricity:* Aylesbury, 45,000*l.*; Ilford, 28,000*l.*; Birmingham, 500,000*l.*; Bristol, 79,000*l.*; Liverpool, 250,000*l.*; Nottingham, 63,000*l.*; Lincoln, 75,000*l.*; Norwich, 60,000*l.*; Leeds, 75,000*l.*; Sheffield, 217,000*l.* *Water:* Mountain Ash, 35,000*l.*; Manchester, 200,000*l.*; Birkenhead, 370,000*l.*; Fylde, 900,000*l.*; Lancaster, 685,000*l.*; Manchester, 2,400,000*l.*; London Metropolitan Water Board, 682,000*l.*; Birmingham, 700,000*l.*; Sheffield, 680,000*l.*; Bradford, 1,156,500*l.*; Burnley, 160,000*l.* *Drainage and Sewage Disposal:* Grays and Tilbury, 44,000*l.*; Rochester and Chatham, 155,000*l.*; *Tramways:* London, 147,000*l.*; Birmingham, 142,000*l.* *Roads and Bridges:* Durham County, 170,000*l.*; Sunderland, 220,000*l.*; Middlesex, 291,000*l.* *Various:* gas, electricity, schools, public walks and pleasure grounds—Plymouth, 35,000*l.* Promenades and sea wall—Blackpool, 187,000*l.*

THE BRITISH ASSOCIATION.—Invitations have been sent to all the old members of the British Association to attend the 87th annual meeting which will be held at Bournemouth on the days Tuesday, September 9, to Saturday, September 13, 1919, under the presidency of the Hon. Sir Charles A. Parsons, F.R.S. The President is to deliver his address on the Tuesday in the Winter Gardens, in which there will also be a reception on the Wednesday, and evening discourses will be delivered on Thursday and Friday. The Municipal College will be the home of the Association; it will contain the reception room, and will accommodate the sections for their meetings. The office of the local secretaries—Messrs. H. Ashling, F. Ibbett and A. B. B. Scott—is in the Municipal Buildings. The presidents of the three sections in which we are more particularly interested are: Section G, Engineering, Professor J. E. Petavel; Section A, Mathematical and Physical Science, Professor Andrew Gray; Section B, Chemistry, Professor P. Phillips Bedson. General excursions are not contemplated, and the meeting as planned will follow the restrictions of the meetings of 1915 and 1916. So far it has not been possible to make arrangements for reduced fares. Early application for accommodation is advisable. Bournemouth has not previously entertained the British Association.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The conditions which have prevailed in the Scotch steel trade during the past few weeks show no change this week, and the demand for plates is about the most outstanding feature. The consumers keep pressing for deliveries and the turnover is consequently very good. There is also a good outlet for general material for the home market, but the buying is still mainly for immediate needs and commitments ahead are not very numerous. The scarcity of hematite must still be noted and in almost all establishments it goes rapidly into consumption soon after being received, and reserve stocks are nil. Makers of angles are not experiencing any great pressure for deliveries, but mills are being kept running full. The demand for supplies of steel sheets, mainly of the heavier gauges, continues brisk, but quite the most of this business is for delivery out of existing contracts. Fresh orders, while fair, are not on a large scale, and in galvanised sheets there is very little doing. Prices are officially unchanged, but very firm. Half the period for which the present rates were fixed is now completed and steelmakers will soon be considering the position with regard to terms for future contracts. As things go at present, and with raw material having a rising tendency, there seems little prospect of lower values in the meantime, but it is too soon yet to make any estimate as to what the steel-makers will arrange when they come together to fix up prices as from the beginning of July. Inquiries for export lots are good, but actual business is very limited owing to the prevailing conditions. If export prices were a shade easier, material more plentiful, and shipping facilities rather better, quite a respectable foreign business would go through, but perhaps the main factor at the moment is the large home demand which leaves very little as available for export.

Malleable Iron Trade.—The West of Scotland malleable iron makers continue to be fully employed, but largely on contracts made some time back. New business is not being fixed up to any large extent owing to the high level of prices and consumers are holding back their orders in the hope of easier terms, but there are at present no signs of an early fall in values. A number of inquiries are on the market, both for home consumption and for export, but only the most urgent are likely to be fixed just at present. The current prices for "crown" bars are 20*l.* 2*s.* 6*d.* per ton, net Glasgow, and round 20*l.* 10*s.* per ton, net f.o.b. Glasgow.

Scotch Pig-Iron Trade.—The predominating feature in the Scotch pig-iron trade is the great scarcity which still prevails and the continued strength of the market. The high prices asked do not seem to cause any check in the demand, as buyers' only concern would appear to be to secure deliveries. At the present time the production of Scotch pig-iron is not equal to the demand, and this is partly accounted for by several furnaces having recently been put off. When the home requirements are so heavy, and not even being satisfied, there is very little available for exporting, with the result that the shipping part of the business is meantime not very large.

Scotch Coal Trade.—There is no falling-off in the demand for Scotch coal and large consumers are securing all that they can lay hands on. With the home buyers taking up so much of what is available, for their own requirements, there is little left over for shipping, and so the export trade is not expanding very rapidly. The output from the mines is not at all satisfactory at the present time, and it is reckoned that half as much more could easily be disposed of if it were on offer. Lanarkshire splint coal is quoted at 35*s.* per ton, and navigation steam coal at from 34*s.* to 35*s.* per ton, both net f.o.b. Glasgow.

Shipbuilding.—The Scotch shipbuilding yards continue to be well employed and a healthy tone prevails. Quite a number of new vessels are on the stocks, but the bulk of the work just now is repairs and the converting of many of the ex-Government ships back to their old trade uses.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Operators during the past week continued to conduct their business on hand-to-mouth lines pending definite news in connection with the promised change in the fixed prices at which, under the limitation scheme, allied countries are supplied with coal. It is now learned that the present fixed prices will become minimum prices, and that sellers will thus be allowed to obtain the best price they can for their coals. The new conditions operate from Monday next (June 2). A change is also to take place in regard to the remuneration of exporters, the chief of which is the substitution of a commission of 2 per cent. on the f.o.b. price in place of 5 per cent. on the f.o.b. price with a maximum of 1*s.* per ton, and less 50 per cent. remitted to the Coal Controller. The 2 per cent. commission is to apply to the sales of all coals irrespective of destination, and, in addition to this, the exporter will receive the full one-third of 5 per cent. brokerage on freight. When these new prices come into operation there will be three different scales of minimum prices, viz., a similar one for bunkers and the Allies, a higher one for Spain and South America, and a still higher one for Holland, Scandinavia, Greece, &c., while for the United Kingdom the price is a maximum one. In the case of bunkers, the Coal Controller has decided that from May 26 last, British fishing vessels are to be supplied at a fixed price, so that in this case the present minimum scale becomes a fixed schedule. It is also expected that firms who are at present unable to participate in the shipment of coals to France, Italy and Belgium will shortly be added to the list of exporters, as it is understood that the Coal Controller has given his sanction to the Local Committees that they may add to the lists of shippers at their discretion. Already exporters are allowed to deal with private importers in Italy provided they can obtain the necessary authorisations, and thus, gradually, the coal trade is returning to pre-war conditions, though export restrictions continue to make business difficult. The strike at the collieries of the Ebbw Vale Company has been terminated and work was re-started by the 5,000 men affected on Monday. It is, however, expected that it will be some time before outputs are brought up to the normal. Against this other sectional stoppages have kept outputs in check. Already coals of all descriptions are extremely scarce and buyers experience difficulty in securing even small isolated parcels. How great the difficulty is can be appreciated by the fact that a small steamer recently left Cardiff with 31 different kinds of coal for cargo, the scarcity of supplies being so great that the shipper was obliged to take odd parcels here and there to make up the required quantity. There is little hope of any improvement in outputs for the miners have been granted three days holiday at Whitsun, while at the end of next month the Royal Show is to be held at Cardiff, and in July the 7-hours' day is to become operative under the Sankey award. Again, with the miners earning more money and fine weather prevailing, many of the colliers are taking their holidays, so that the prospects of an increase in production are remote. In fact, the likelihood is that there will be a further decrease. Meanwhile prices rule firm, and for France and Italy sellers can secure 5*s.* above the schedule figures, while the same premium is demanded for Spain, though for South America salesmen are willing to accept the minimum prices. The inquiry for Holland and Scandinavian countries, for which the top schedule is applicable, is practically negligible. In the bunker market supplies are scarce, and for allied vessels prices ranged from 7*s.* 6*d.* to 10*s.* above the scale, and for neutral steamers a premium of from 10*s.* to 15*s.* was asked and received.

Newport.—Monmouthshire coals of all classes remain scarce and totally insufficient to meet the demand. For cargo purposes business is restricted by operators following a waiting policy pending news regarding the promised changes in the allied schedule, and for Spain prices ranged from 1*s.* 6*d.* to 2*s.* 6*d.* above the minimum scale. For bunkers, sellers demand anything from 7*s.* 6*d.* to 10*s.* above the schedule for allied vessels, and good large Monmouthshire coals readily fetch round 45*s.* For neutral steamers a premium of from 10*s.* to 15*s.* is demanded, and Eastern Valley, Western Valley and Black Vein large realised anything from 50*s.*, with best steam large up to 55*s.* It is hoped that the output of Monmouthshire coals will shortly be increased owing to the resumption of work at the pits of the Ebbw Vale Company, which have been idle for the past fortnight. Mr. Frederick Mills, the managing director of the company, in an interview with the men's representatives, made some interesting and important observations. He said the men had stopped work on 141 occasions during the war, and also since the armistice, on all sorts of odd moments and inconvenient times without warning or negotiation. In twenty years the wages had increased from 500,000*l.* to 3,000,000*l.* per annum, and he asked if it was seriously suggested that the company with all its resources were such simpletons as to refuse to provide the men with the means of getting a good output.

MACHINE TOOLS, WOOD-WORKING MACHINERY AND TREADLE LATHES.—With reference to the Machine Tool and Power Machinery Order, 1916, dated August 28, 1916; the Wood-Working Machinery Order, 1917, dated June 5, 1917; the Treadle Lathes Order, 1918, dated April 15, 1918; the Minister of Munitions ordered, on the 23rd inst., as follows: (1) The operation of the said Orders is hereby suspended on and after May 23, 1919, until further notice. (2) Such suspension shall not affect the previous operation of the said Orders or any of them or the validity of any action taken thereunder or the liability to any penalty or punishment in respect of any contravention or failure to comply with the said Orders or any of them prior to such suspension or any proceeding or remedy in respect of such penalty or punishment. (3) This Order may be cited as the Machine Tool, Wood-Working Machinery and Treadle Lathes (Suspension) Order, 1919.

THE ATLANTIC FLIGHT.—From a communication which has reached us from the Fiat Company, of Turin, we learn that this firm have decided to attempt the Atlantic flight with a new design of aeroplane they have recently produced. The machine, which is a biplane, will be fitted with a single 12-cylinder engine, of 700 h.p. This, it is claimed, will be the most powerful aero-engine constructed, and it is expected to give the machine a speed sufficiently high to enable the journey to be completed in 14 hours. We gather that the fuselage will be constructed of sheet steel, and divided into compartments in which the supply of petrol will be carried. The arrangements are such that this part of the machine can be used for life-saving purposes in the event of a forced descent on to the sea. In connection with the proposed Atlantic crossing we may perhaps recall the fact that Fiat machines have already accomplished some noteworthy long-distance flights, including one from Turin to Naples and back, without landing, a distance of about 1,000 miles, in 10½ hours, and another from Turin to London without a stop, a distance of 750 miles in 6½ hours.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, May 30, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. Discussion on the following paper will be resumed by Dr. Walter Rosenhain, F.R.S., "The Mechanical Properties of Steel, with some Consideration of the Question of Brittleness," by Mr. W. H. Hatfield, D.Met., of Sheffield, Associate Member.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, June 2, at 7.30 p.m., an informal meeting will be held in the rooms of the Chartered Institute of Patent Agents, Staple Inn Buildings (South Block), close to No. 335, High Holborn, W.C., when Major Kenelm Edgcumbe, R.E., will open a discussion on "The Vicious Circle of Increasing Prices."

THE SOCIETY OF ENGINEERS.—Monday, June 2, at 5.30 p.m., informal meeting in the Apartments of the Geological Society, Burlington House, Piccadilly. During the course of the evening a short Lantern Lecture will be delivered by Mr. A. Stewart Buckle, Member of Council, on his recent visit to France as a member of the Commission appointed by the Ministry of Labour for the Resettlement of Officers in Civil Life. Mr. T. J. Gueritte, Fellow and Member of Council, who has just returned from a visit to the Palais National de Versailles, will give a 15 minutes' talk on "The Unknown Versailles," illustrated by lantern slides.

THE RÖNTGEN SOCIETY.—Tuesday, June 3, at 8.15 p.m., at the Royal Society of Arts, 18, John-street, Adelphi, W.C. 2. Annual General Meeting, followed by Ordinary General Meeting. Paper and demonstration by Mr. N. E. Luboshey, "The Photographic Side of Radiography and the Use of Intensifying Screens" (continuation of paper read June 4, 1918).

THE ROYAL SOCIETY OF ARTS.—Thursday, June 5, at 4.30 p.m., Indian Section. "Aviation as Affecting India," by Brigadier-General Lord Montagu of Beaulieu, C.S.I., V.D., F.R.Met.Soc., Assoc.Inst.C.E., A.I.Mech.E. Adviser on Mechanical Transport Services to the Government of India. Chairman, Major-General the Right Hon. John E. B. Seely, C.B., C.M.G., D.S.O., M.P.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, June 6, at 5.30 p.m., a discourse will be delivered by Professor Sir Ernest Rutherford, LL.D., D.Sc., F.R.S., M.R.I. The subject will be "Atomic Projectiles and their Collisions with Light Atoms." Afternoon Lectures, at 3 p.m.: Tuesday, June 3, Professor W. H. Bragg, C.B.E., D.Sc., F.R.S., on "Listening Under Water" (The Tyndall Lectures) (Lecture II). Thursday, June 5, Sir Valentine Chirol on "The Balkans" (Lecture II). Saturday, June 7, Mr. J. M. Price, War Artist Correspondent of *The Illustrated London News* with the Italian Army, "The Italian Front," illustrated by cinematograph films lent by the Italian Government (Lecture II).

THE ROYAL SANITARY INSTITUTE.—This Institute will hold a Congress at Newcastle-upon-Tyne, from July 28 to August 2. Particulars can be had from the Secretary, 90, Buckingham Palace-road, S.W. 1.

INDUSTRIAL ESSAY COMPETITION.—*Unity*, the organ of the National Alliance of Employers and Employed, offers prizes amounting to 200*l.*—presented by Sir Robert Hadfield, Bart.—for the best essay on either of the following subjects: A practical scheme for the joint development of industry by Capital and Labour; the most effective means for the prevention of unemployment; the most effective means for the prevention of industrial disputes. There are to be one first prize of 100*l.*, one second prize of 50*l.*, one third prize of 10*l.*, and eight prizes of 5*l.* each. The Committee of Award will consist of: The Right Hon. Frederick Huth Jackson, P.C. (chairman of the National Alliance of Employers and Employed); the Master of Balliol College, Oxford; the Right Hon. Arthur Henderson, P.C. The competition closes on August 30, 1919. Further information can be obtained from *Unity*, 64, Victoria-street, London, S.W. 1.

EXPLOSIVE AMMONIACAL SILVER OXIDE.—The Department of Customs, Ottawa, Canada, directs attention to the dangers which the handling of ammoniacal silver solution involves. Several explosions have recently occurred in the analytical laboratory of the department, and it is pointed out that the exclusion of air did not prevent the formation of explosive silver nitride. The dangers are very real; but it might be remarked that there are several explosive silver compounds between silver and nitrogen, only one of which certainly contains oxygen; the constitution of these compounds are not quite settled, though they are all theoretically very interesting. The nitride, generally called azide, AgN_3, is a salt of the acid HN_3 which was first prepared by Curtius from organic compounds; the acid is a colourless liquid, safe in aqueous solutions, but its vapours are poisonous, and the anhydride is explosive. By treating silver oxide with concentrated aqueous ammonia the azide AgN_3 is obtained as a black crystalline powder which when dry is as explosive as the iodine nitride N_3I, which was known long before the azides. There is, further, Berthollet's so-called silver fulminate, probably an amide $AgNH_2$, and in addition the silver fulminate proper $Ag_2N_2C_2O_2$; this latter corresponds to the mercury fulminate $HgC_2N_2O_2$ discovered by Howard in 1799, the common detonator of explosive caps and fuses, but is still more explosive. The fulminates are prepared simply by dissolving the metal in nitric acid and adding alcohol to the solution; the fulminates are isomers to the non-explosive cyanates.

HEAVY OIL ENGINES OF THE MOTOR SHIP "SANTA MARGHERITA."

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, NAVAL CONSTRUCTION WORKS, BARROW-IN-FURNESS.

(*For Description, see Page* 691.)

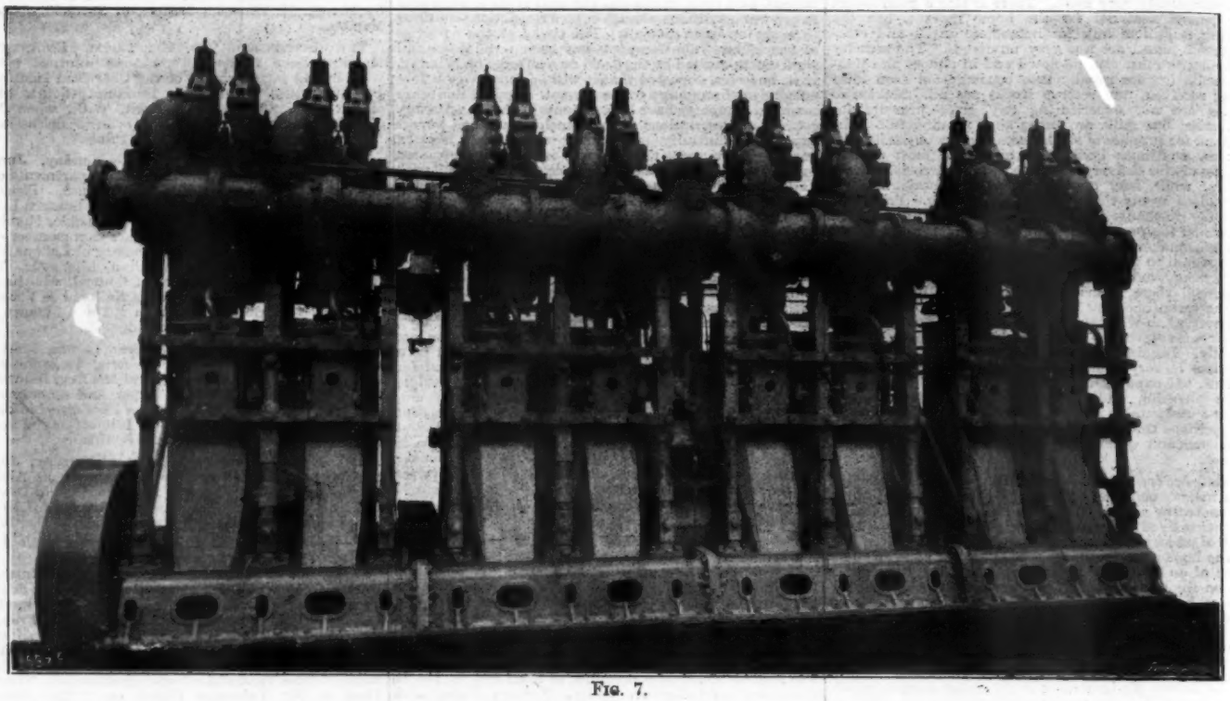


FIG. 7.

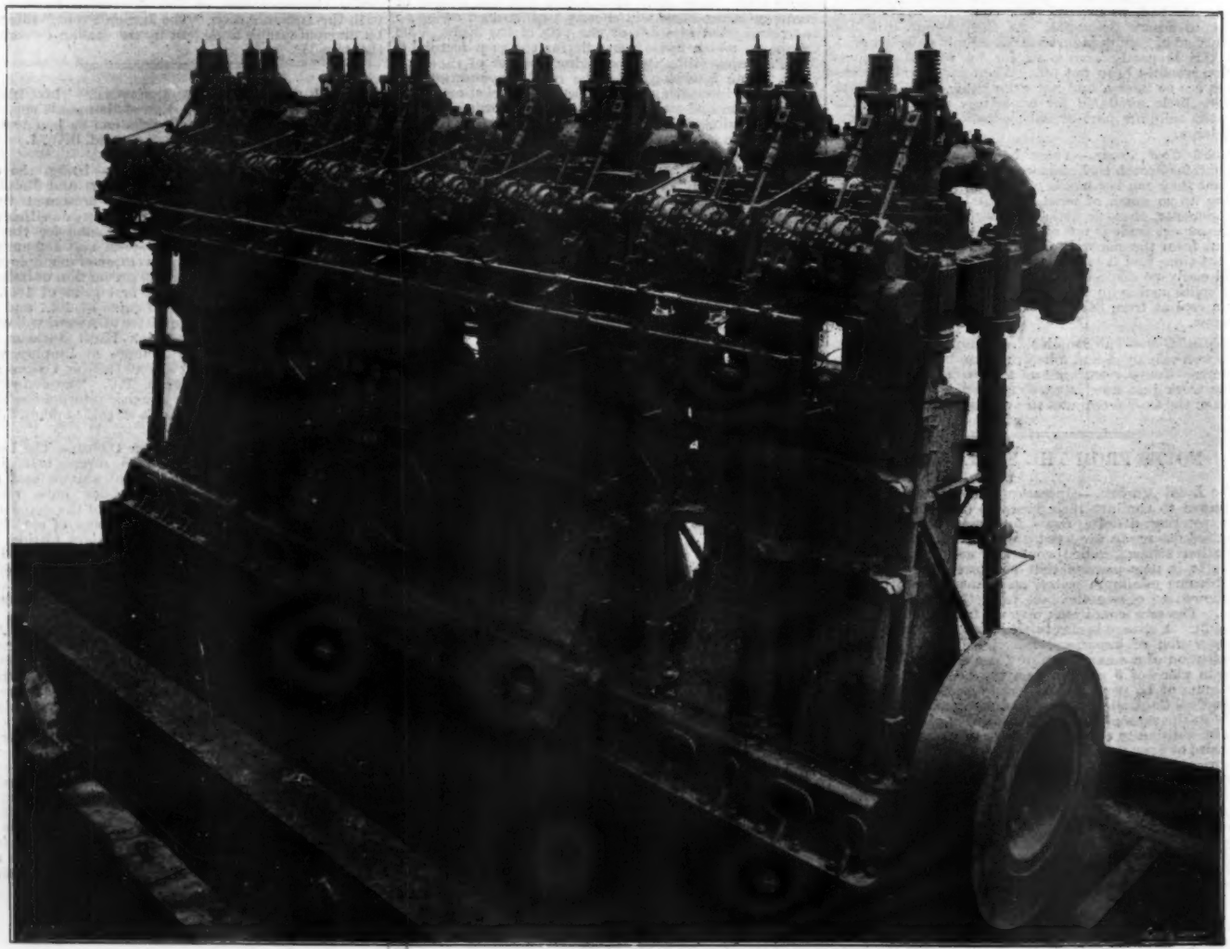


FIG. 8.

GENERAL ARRANGEMENT OF THE HEAVY-OIL PROPELLING M

CONSTRUCTED BY MESSRS. VICKERS LIMITED, NAVAL

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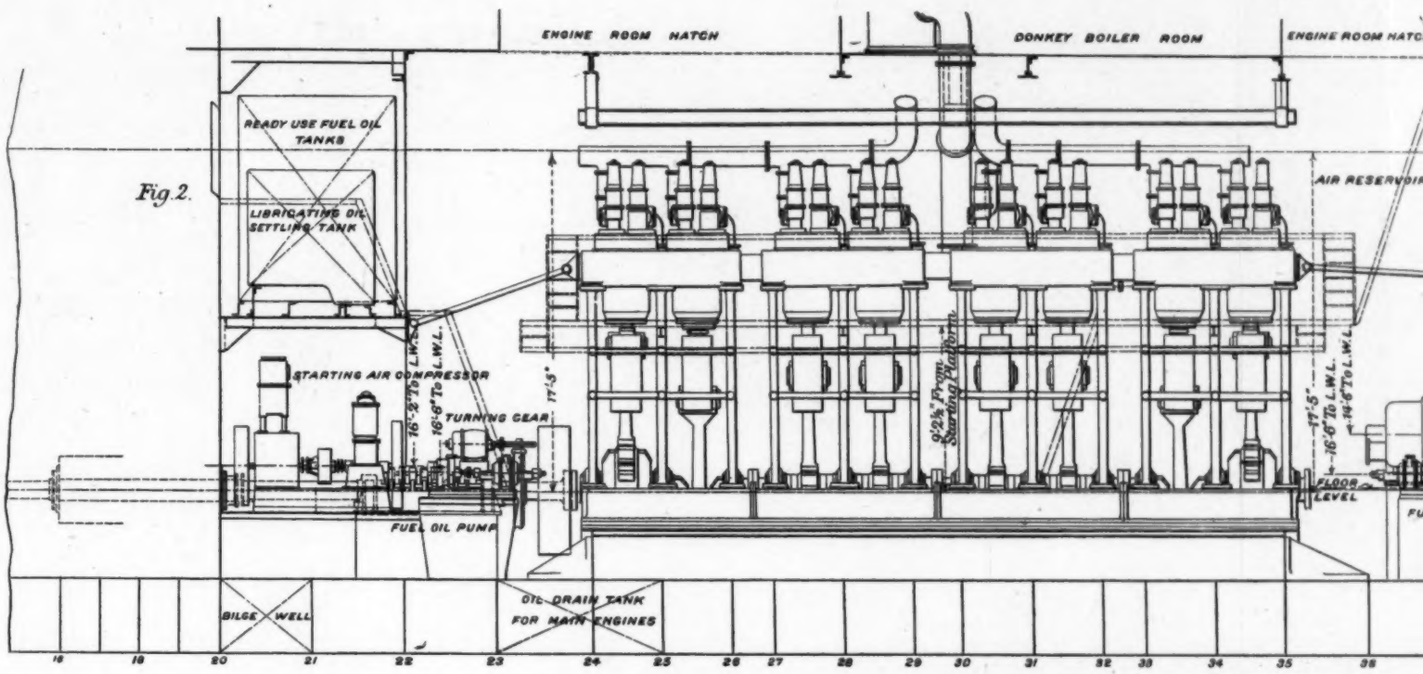
Fig. 2.



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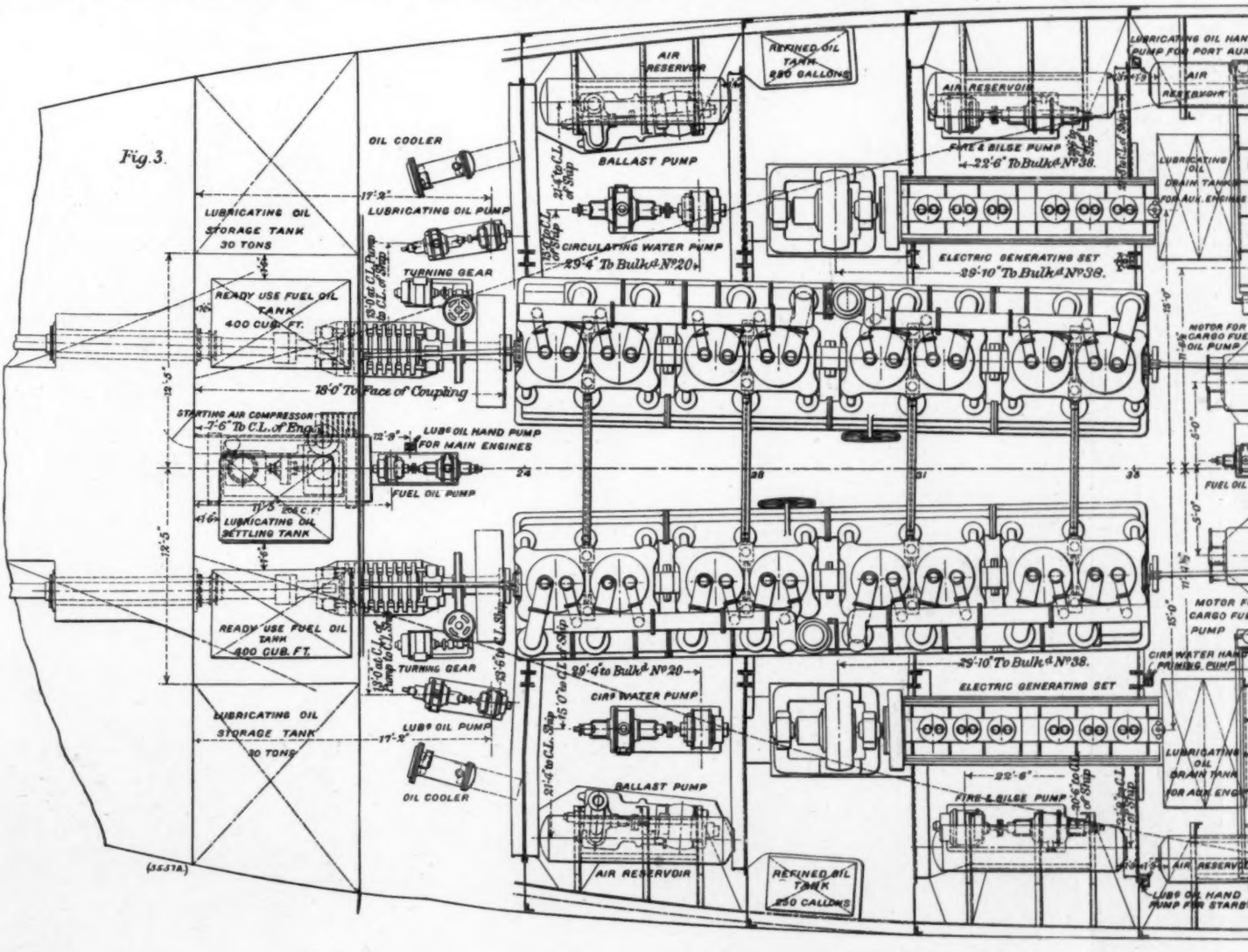
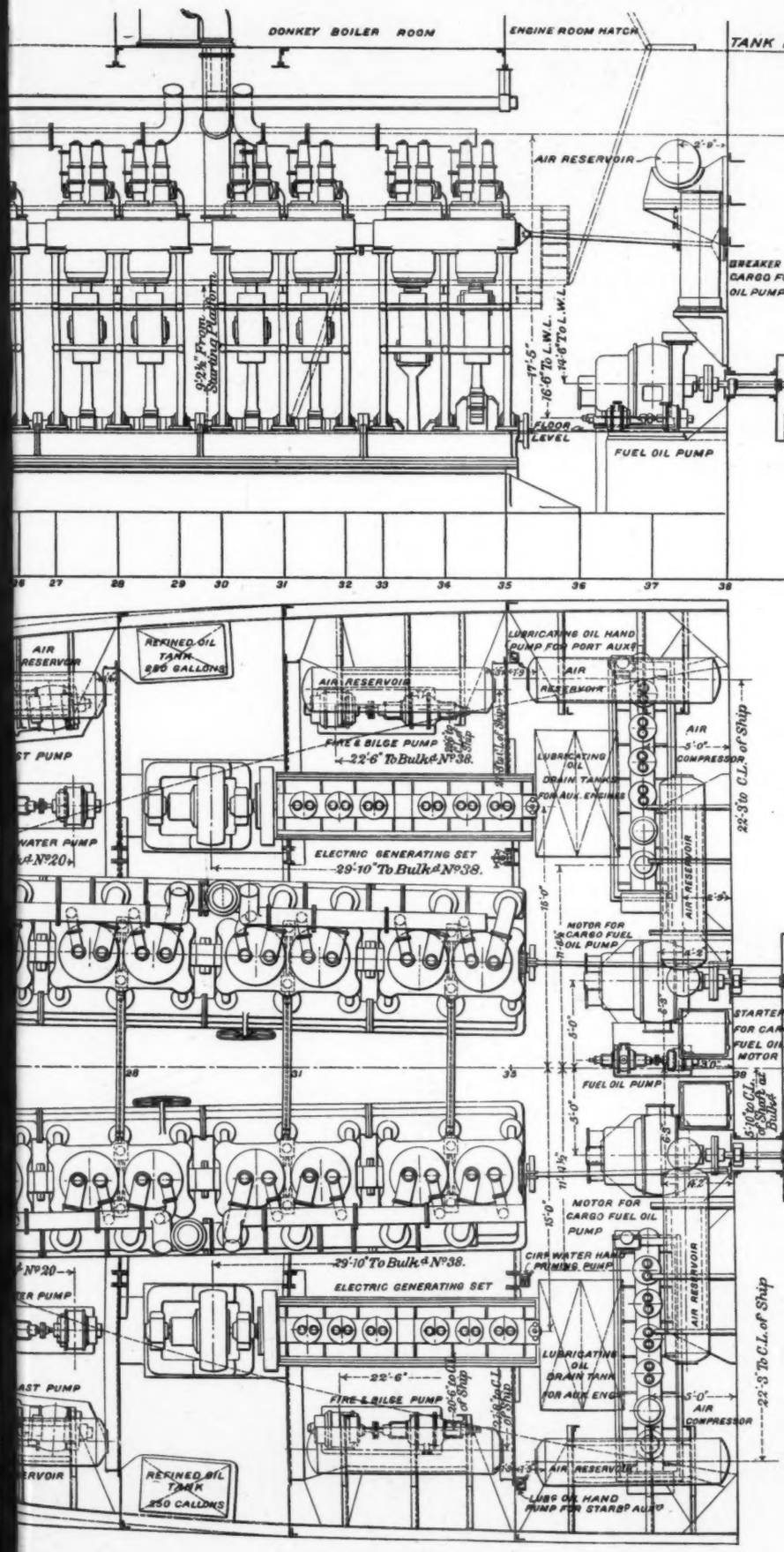


OF THE HEAVY-OIL PROPELLING MACHINE

CONSTRUCTED BY MESSRS. VICKERS LIMITED, NAVAL CONSTRUCTION

(*For Description, see Page* 691.)


DONKEY BOILER ROOM
ENGINE ROOM HATCH
AIR RESERVOIR
FUEL OIL PUMP
FLOOR LEVEL
REFINED OIL TANK 250 GALLONS
LUBRICATING OIL HAND PUMP FOR PORT AUX.
FIRE & BILGE PUMP
22'-6" To Bulk.d N°38.
ELECTRIC GENERATING SET
29'-10" To Bulk.d N°38.
LUBRICATING OIL DRAIN TANK FOR AUX. ENGINES
AIR COMPRESSOR
MOTOR FOR CARGO FUEL OIL PUMP
CIRC WATER HAND PRIMING PUMP
LUBRICATING OIL DRAIN TANK FOR AUX. ENGS
LUB OIL HAND PUMP FOR STARB.D AUX.
22'-3" to C.L. of Ship

HINERY OF THE MOTOR SHIP "SANTA MARGHERITA."

RUCTION WORKS, BARROW-IN-FURNESS.

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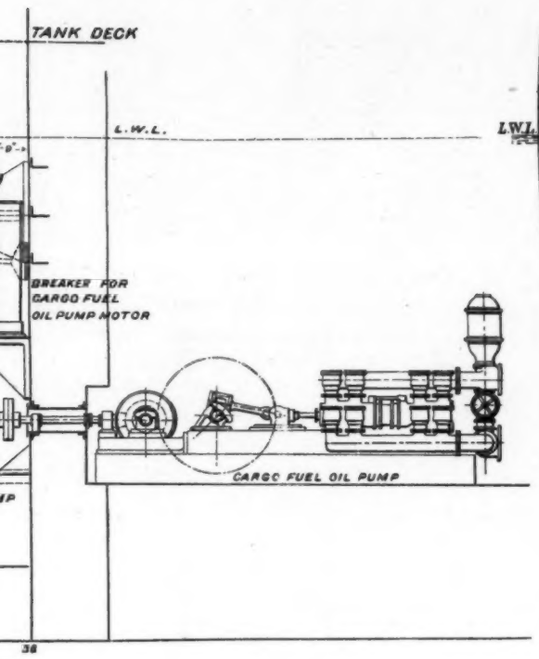

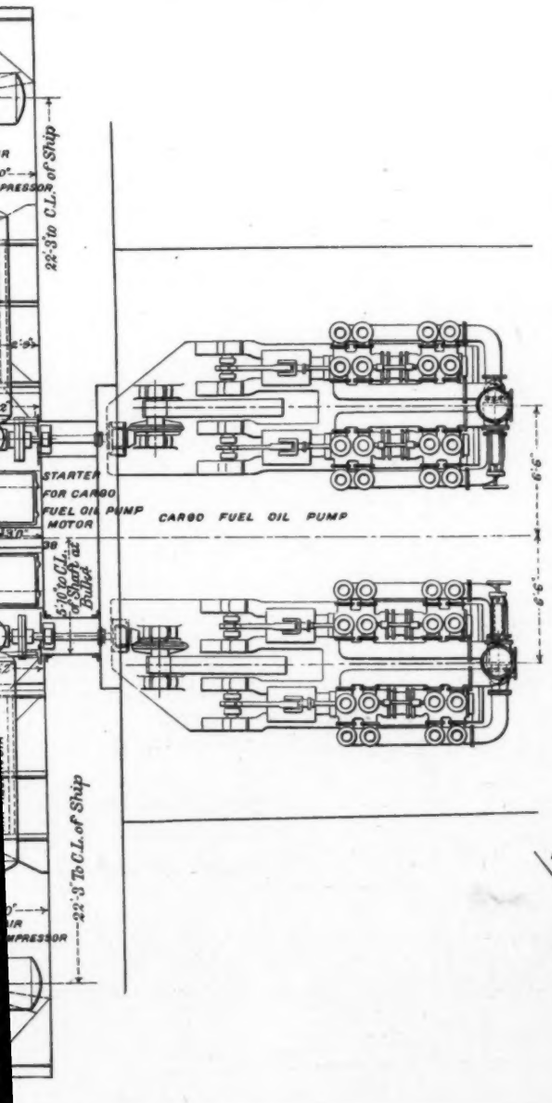
22'3" To C.L. of Ship
STARTER FOR CARGO FUEL OIL PUMP MOTOR
CARGO FUEL OIL PUMP
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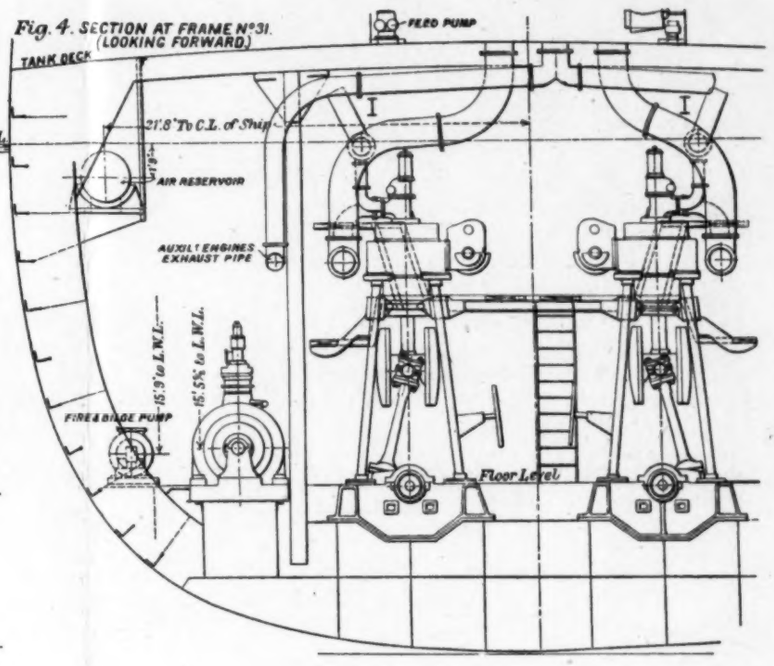
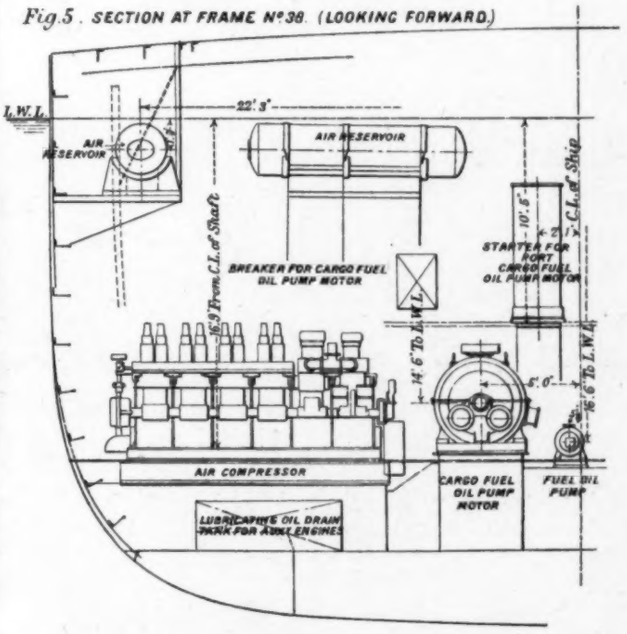
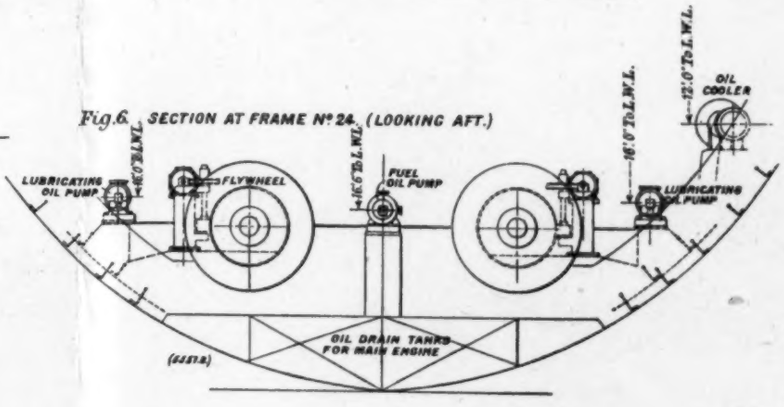
6'6"
5'0" To C.L. of Shaft at Bulkhead
22'3" To C.L. of Ship







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For Advertisements, J. S. Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication, and certainly not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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Thick " "	£2 9 6
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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—8682 and 8686 GERRARD.

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With a Two-Page Plate of the GENERAL ARRANGEMENT OF THE HEAVY-OIL PROPELLING MACHINERY OF THE MOTOR SHIP "SANTA MARGHERITA."

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 705.

ENGINEERING.

FRIDAY, MAY 30, 1919.

THE WAGES BASIS.

THE suggestion that the Government should set up a Commission with wide terms of reference to report on the principle of minimum rates of wages prior to the framing of legislative machinery for the enforcement of such minimum rates, which was put forward by the National Industrial Council, has been accepted by the Prime Minister, and thus one of the most important and most difficult problems of industry will, we trust, be subjected to a thorough investigation which cannot fail to be instructive and which it may be hoped will be productive of a satisfactory basis of remuneration for all workers. It is satisfactory to note that the Prime Minister fully recognises the difficult nature of the problem before the Commission and the impossibility of introducing legislation until the principle involved has been fully worked out.

A recent strike of carpenters and joiners for a minimum wage of 5*l.* per week was symptomatic of a very general feeling of unrest and dissatisfaction among many classes of worker—a feeling which was based very largely upon the difference in weekly earnings as between different trades engaged in the same industry and aggravated by the inflated war wages paid to certain classes of worker. That the dissatisfaction with the existing condition was not confined to manual workers was evidenced recently by the lengthy discussion on the status and remuneration of draughtsmen and the subsequent formation of an Association of Draughtsmen having as its object the improvement of status and remuneration of its members. Less apparent but none the less real is the very strong feeling of resentment among foremen and staff at the wholly inadequate additions which have been made to their salaries in comparison with the increases awarded to manual workers; indeed, at the present moment the ridiculous position in many trades exists whereby the manual worker may earn far more than the head foreman who directs him and accepts all responsibility for the work of the department, while not infrequently the worker earns more than those who direct the head foreman. Undoubtedly there is a very strong and general feeling that the present wages basis as between trades and as between manual and brain workers is altogether wrong, and it is to be hoped that the forthcoming Commission may be able to do something to remedy the present illogical position.

As between trades the present differences in wage rates are due in a large measure to the operation of the ordinary laws of supply and demand, and are further complicated by the fact that systems of payment by result have been introduced in certain trades and not in others. A further important influence affecting wages is the action of numerically strong trades unions in fighting for higher wages for their members—the stronger unions naturally coming off best in this form of bargaining. That all this forms a wholly illogical basis upon which to determine the value of the work done by different trades in any industry is evident, and the differences in rates of wages which at present exist between different trades are but the natural consequence of these conditions. As evidence of the difficult nature of the problem of arriving at a satisfactory wage basis, the case of workers exposed to the weather may be cited. The influence of weather conditions on the continuity of work in many shipbuilding trades, and in house building and other industries is very considerable, and is of such variable extent that it is difficult to make allowance for it, but it is obvious that the fact that a willing worker may only be able to work a portion of the possible time through inclement weather must in justice be given due weight in fixing the wages basis of his trade relative to that of a trade which is carried on in comfort and under cover.

Severe and prolonged physical effort such as is met with in riveting, forging, puddling, mining, &c., involves considerations of a physiological character bearing upon the nature and amount of food required and upon the physical endurance of the worker over a period of years. In the case of riveters this is further complicated by the consideration of the influence of weather conditions already mentioned. Many considerations such as the above must be allowed for in coming to any decision as to an equitable wage basis, but what may be called the physical difficulties so far named are simple of solution when compared with the problem of differentiating between mental and physical effort, and in assigning a wage value to the former.

It is well to recognise the fact that mental and physical effort cannot be reduced to a common denominator, also that the degree of mental effort required for the satisfactory performance of the operations of one trade may be very much greater or less than that required for any other trade. Thus the mental effort required of, say a riveter, in the performance of his duties is not of the same order as that required of a scientific instrument designer, neither are the physical efforts of the two workers in any way comparable. Similarly, the mental effort of a head foreman is vastly greater than that of the worker he directs, while the physical effort of the latter is greater than that of the foreman, yet in many cases the wage award to the worker is higher than that to the foreman under present conditions. It should be one of the functions of the forthcoming Commission firmly to establish the principle that mental effort is of a higher order than physical effort and to assign it an appropriate wage value. In this connection it is of interest to note that in the National Industrial Council as originally constituted we believe that there was not one representative of the technical staffs employed in the various industries.

If the present strong effort which is being made to develop technical and trade education means anything higher than the mere production of more efficient profit-making units it surely points to the belief that the more brain power is developed and utilised by the worker in the performance of his daily task the more useful and profitable does he become to his employer and the community, and the higher therefore should be his earnings. This applies equally to the manual and the brain worker, and points to a recognition—at least in theory—of the value of technical training and knowledge for workers, a recognition which it is to be hoped may in the future find more adequate expression in a revised wage basis. We have repeatedly called attention in these columns to the wholly inadequate recognition which is given to brain workers in this country—the wages offered to trained works, chemists, draughtsmen, &c., are at present little, if any, better than those of a piecework labourer—and the same lack of recognition of the varying degrees of mental effort required in the performance of the different classes of manual work is evident in the wage rates of the various trades.

Undoubtedly the fixing of the relative wage rates as between trades is a problem bristling with difficulties, but careful consideration of the factors bearing upon the problem would assist in establishing a basis which at least would be founded upon a reasoned analysis of the claims of each class of labour. Of these factors the following are probably the most important:—(1) Degree of mental skill and training required; (2) degree of manual skill required; (3) degree of continuity of work; (4) degree of liability to accident; (5) probable length of working life; (6) available supply of suitable workers.

It will probably be admitted by most people, in theory at least, that mental effort is of higher wage value than manual skill and the varying degree to which mental effort must accompany manual skill must therefore profoundly affect the basis wage rate as between trades. The time and money spent on the acquisition of technical skill are usually quite inconsiderable on the part of manual workers, while in the case of those who intend to take up the higher branches of industry the expenditure of

time and money is very considerable, and is additional to the ordinary time of apprenticeship spent in the shops in the acquisition of practical knowledge and manual skill. The degree of manual skill required for the satisfactory performance of the work of each trade varies considerably and is roughly proportional to the time taken by the average worker to acquire average skill. On this basis the disproportion between the time taken to train an average pneumatic riveter and an average engineer is most marked, but this is not reflected in the wage rates paid to these trades.

While the degree of skill required would seem to be the factor which should dominate the theoretical wage value of each trade the remaining factors set out above must be allowed to exercise their due weight in the final determination of relative wage values. Work which is liable to interruption through bad weather should be paid at a higher rate than similar work which can be carried on continuously, the increase in rate being based on the average time lost through stoppage for bad weather. Temporary loss of earning power owing to accident is a factor which should be taken into account, as the allowance made to workers during their enforced idleness due to accident, although usually based upon their average earnings, is usually small in comparison with these latter. Liability to accidental injury is naturally greater in certain trades than in others, and statistics taken over a number of years for each trade should provide a basis for an equitable assessment of the average loss due to this cause.

The degree of physical effort required naturally varies in different trades, and it is obvious that work which demands the highest physical effort cannot be sustained for the same period of years as work of a less physically strenuous nature, provided that, as at present, all trades work the same number of hours per day. In practice this effect is shown in the numbers of elderly and less physically fit men who drop into the less strenuous and lower paid branches of their trade. The earnings of workers in such trades during their physically efficient period should obviously be such as to compensate for the earlier decline of their earning capacity. The importance of the factor of number of suitable workers available was amply demonstrated during the strenuous days of war work when lack of workers was one of the contributory causes of higher wages. It is, however, difficult to justify any variation of the wage value of work done because of the fact that there happens at any particular time to be more or fewer competent men available than are necessary, and in any equitable adjustment of wage values it does not seem necessary to take this factor into account.

That present wage values have little, if any, relation to value of work done is certain, but it is equally certain that any attempt to readjust them upon any reasoned basis will meet with most strenuous opposition from many quarters. The factors governing any readjustment are many and their relative values difficult to assess, but consideration of the subject upon the lines suggested could not fail to be of interest and would certainly point to the need for some modifications of present wage values as between trades. If, however, investigation leads to the recognition of the long overdue claims of the brainworkers in all departments of industry a great step in advance will have been made and one which will give tangible support to the call for a higher standard of education.

A COMBINED INTERNAL-COMBUSTION AND STEAM ENGINE.

IT is common knowledge that the internal-combustion engine has a higher thermal efficiency than the steam engine. It converts a greater proportion of the heat in the fuel which it uses into useful work, and this greater proportion is by no means trivial in amount. In many forms the internal-combustion engine is also an entirely practical proposition. These things are admitted on all hands, and yet, in spite of growing fuel costs, the internal-combustion engine fails to eliminate the steam engine and for the larger powers fails even to keep up with it. It is only in special fields in which its peculiar attributes are not objectionable, or are even virtues, that the internal-combustion engine holds its own. The reasons for this position of affairs briefly are that the internal-combustion engine cannot start without some external source of power, that it cannot develop its full power except at full speed, that it is a poor performer at low speed and can carry but little overload. Also it may cease to operate without warning. A further consideration is that when large powers are reached great practical difficulties are encountered in construction. It appears probable that if the internal-combustion engine is to become a serious rival to the steam engine—which in this connection may be read steam turbine—for large powers then this last consideration in particular must be overcome.

In a paper read before the Royal Society of Arts, on the 26th inst., Captain F. E. D. Acland described an engine which has been developed by Mr. W. J. Still, and which represents an attempt both to improve the efficiency of the internal-combustion engine and to eliminate some of its undesirable characteristics. Briefly the Still engine is an internal combustion engine, the cylinder of which is jacketed with hot water at constant temperature. Heat abstracted from the combustion cylinder is employed not in raising the temperature of the jacket water, but in converting it into steam. The jacket is connected up to the water space of a steam boiler and this water, on its journey to the jacket, is taken through a tubular heater through which the exhaust gases pass. The steam and water leaving the jacket are led to the steam space of the same boiler. The exhaust gases, on leaving the tubular heater are taken through a second heater, through which the feed water is drawn. The steam from the boiler is used in a steam cylinder which forms the underside of the combustion cylinder. That is to say, there is but one piston and one cylinder, the upper part of which is an internal-combustion cylinder and the lower part of which is a steam cylinder. The down stroke is an internal-combustion stroke, and the up stroke a steam stroke. For the sake of clarity we have described the engine in its simplest form, but naturally there may be more than one of the combined cylinders, and part of the steam may be used in separate cylinders, compounded or otherwise.

Remarkable economies are claimed for this engine, and theoretically they may be admitted. It is stated that a final exhaust temperature as low as 150 deg. F. is obtained, so that the working temperature range is very large. The arguments for economy are based on the following main considerations. The high jacket temperature results in a higher mean temperature than usual in the combustion stroke, which improves efficiency. All heat rejected to the jacket is recovered directly as steam and not in the form of hot water difficult to use effectively. The steam cylinder, it is claimed, gives unusually good results, since as the cylinder is preheated by the combustion stroke there is no condensation and the steam is rejected to exhaust slightly superheated. From an operating point of view it is claimed that as the steam warms the engine before starting there are no sudden temperature changes, and that the steam allows the engine to be started against load. In Still-Diesel engines it is further claimed the compression pressure may be reduced by 50 per cent. with entirely reliable ignition, owing to the higher mean temperature of the cylinder. This simplifies constructional difficulties.

The engine is a very interesting one and it is to be hoped it may be developed and become of importance, but it would appear that it will have to demonstrate its practicability in a very definite way before it can be unreservedly accepted. Confining ourselves for the moment to large sizes, it will be interesting to consider how the engine compares with, say, a large gas engine. Such engines have partially failed, and are failing, to make way on the score of practical considerations and we fear it is not clear that the Still engine, accepting its qualifications on the reports of its sponsors, eliminates the points which in large gas engines have given trouble. It might not unreasonably be suggested that from this point of view the Still engine introduces new ones. Clearly it is a complicated machine, and the main cylinder troubles of a large gas engine would appear to be retained. It must be admitted, however, that the high efficiency claimed makes the large gas engine better worth fighting for than ever.

We have no wish to take up an attitude of opposition on the question of the mechanical running of the engine. Indeed we would be precluded from doing so, even if we wished it, from the fact that unfortunately little or no practical detail was described in Captain Acland's paper. The only feature on which a detail of construction was included was in connection with the cross-section of the cylinder and jacket. The cylinder proper, in, for instance, a Still gas engine, is made of metal approximately one-third, or one-fourth, of the usual thickness. It is ribbed on the outside to increase the surface in contact with the jacket water. The ribs are machined on their outer ends and the whole is enclosed in a steel outer cylinder which forms the jacket, and at the same time supplies the necessary strength to enable the cylinder to stand up to the internal stresses. It is stated that no failure of a cylinder has ever occurred. It is particularly claimed in connection with this construction, and in view of the fact that the jacket water is of constant temperature throughout, that stresses in the cylinder, due to cold water at the inlet and hot water at the outlet, met with in ordinary cylinders, are suppressed in the Still engine. There is possibly something in this, but none the less a uniform wall temperature is hardly likely to be achieved, while the high mean temperature would appear to suggest lubrication difficulties.

Apart from increased efficiency, it is clear that the Still engine, in virtue of its steam feature, also attempts to improve the flexibility and starting properties of the internal-combustion engine. This, however, is only done by adding all the features of a steam engine to it. Dealing above with the claims made for the engine, we referred to the statements that there was no sudden temperature changes at starting and that it could be started against load. If, however, we understand the engine correctly these features can only be obtained by fitting the boiler with an independent fire-box and raising steam before the engine is started. This, of course, can be done, and the independent fire-box is a feature of some applications of the engine, but these peculiar starting virtues of the steam engine have only been obtained by sacrificing one of the main claims of the internal-combustion engine—that is, that it requires no external boiler and can be started up at any time on short notice and without preliminary preparation.

We shall be expected to say something of the actual performance of the engine and its test results, and in this connection we must say that we think Mr. Still and Captain Acland brought the engine to public notice in a somewhat unfortunate way. The paper read on the 26th inst. confined itself too much to generalities. Detailed information about the construction of one actual engine, together with complete results of an adequate test—preferably by an independent authority—would have carried much more conviction. To quote some of the figures that were given, however, we may refer to tests on a four-stroke single-cylinder engine described as of the explosion type. The class of fuel used was not stated nor was the power or size of the engine, which, however, we take to have been small as the test was an early one. In this case 29 per cent. additional brake horse-power was added to the shaft of the engine without increase in the fuel consumption and with steam exhaust to atmosphere. The addition of a condenser raised the added brake horse-power to 40. It was stated, however, that the air pump was driven separately. As we read the figures nothing has been debited from the engine for this work, and this is an illustration of an aspect of the paper which leads to our plea for complete results of one test.

A single-cylinder petrol engine, with condenser at the steam end maintaining 25-in. vacuum, had a brake thermal efficiency of 36 per cent. and used an average of 0·42 lb. of fuel per brake horse-power over a 4-hours' run. Again, however, the condenser pump losses were not included. A Still-Diesel

engine with compounded steam side had a consumption of 0·302 lb. of Admiralty shale oil per brake horse-power over 1 hour's run. "Scavenge pump not included." This engine developed 330 brake horse-power under waste heat conditions. Several figures are given for the output of this engine with extra added steam, but they are not material from our present point of view. A good deal of practical work appears to have been done in running these engines with added steam. As we understand it the idea is that for both marine and locomotive work the possibility of such added steam is looked upon as an important possibility of the engine. For normal running waste-heat steam only would be employed, but at starting and for overload the added steam would give the flexibility of an ordinary steam engine.

THE ROYAL SOCIETY SOIRÉE.

THE Royal Society Soirée of last Wednesday was the first held since 1914. Five years of war and epidemics have sadly thinned the ranks of the Fellows of the Royal Society, as of those of other bodies. Many familiar faces will never be seen again in Burlington House, and many gaps have been filled up. In the Council Chamber, in which Sir William Crookes had stood in June, 1914, as president of that year, Sir Joseph J. Thomson, O.M., welcomed the Fellows of the Royal Society and their guests last Wednesday. The attendance was not unusually large. The exhibits of scientific novelties were not so numerous as might have been expected in view of the suspension of these gatherings for a long period during which an intense and fruitful activity has prevailed in many fields. "The lid is not quite off," to use a phrase often heard at present; the originators of inventions still undergoing development in particular remain tied down to a certain extent and may prefer to present full accounts of their innovations and researches in due course to having preliminary notices published for which they are not themselves responsible. Yet the exhibits were certainly most interesting, and our difficulty will be to deal adequately with the apparatus and results of researches in the space at disposal. We will begin our notice with exhibits in which the engineer is more particularly concerned.

Professor Ernest Wilson showed a portable instrument he has designed and used for measuring the susceptibilities of ores and rocks in magnetic surveying work. The instrument comprises two polarised permanent magnetic rings placed horizontally one above the other, and fitting round two soft iron pole pieces which are arranged along a diameter of the rings. Between the two pole pieces, and in the axis of the rings, is a cylindrical air gap in which the specimen to be tested is suspended from one end of a balanced lever. The lever itself is suspended by a fairly stout strip of phosphor bronze, which is attached, at its upper end, to a torsion head. A pointer attached to the lever moves over a scale of degrees on the torsion head and serves to indicate the position of the lever and the specimen. Below the lever is a vane immersed in a cup of oil which damps the oscillations of the lever. The field in the air gap can be varied by rotating the two magnetised rings relatively to each other, so that their poles assist or oppose each other more or less. To use the instrument the specimen, which must be cylindrical in form, is attached to the lever and placed in the air gap. The torsion head is then rotated until the specimen suddenly moves laterally out of the gap, and the angular position of the torsion head at which this occurs is noted. The reading is then repeated in the opposite direction, and the mean of the two readings thus obtained is a measure of the magnetic force on the specimen. It can be shown that the magnetic susceptibility $K = \frac{C\theta}{H^2 V}$, where C is a constant of the instrument, θ is the angle of deflection measured by the torsion head, H is the strength of the field in the gap, and V is the volume of the specimen. The field H has, of course, to be determined for different positions of the magnetic rings, but once found it can be included in a calibration curve for the instrument. By this instrument extremely low susceptibilities can be determined with great ease and accuracy. That of a normal solution of magnesium sulphate, which was measured in a small glass test tube, was found to be 0·000018, and much lower readings than this can be quite easily obtained since the deflection of the torsion head in this particular measurement was 40 deg. During the war the instrument has been used for survey work in connection with the utilisation of the low-grade iron ores in the Midlands. For the ironstone of the Melton Mowbray district the value of K was about 0·0003, as compared with magnetite, which ranges from 3 or 4 down to 0·1, and red hematite for which the value is about 0·0002. For grey granite the susceptibility varies from 0·001 to 0·002, and for ruby mica its value is as low as 0·000012. Limestones are even less magnetic, the value of K being of the order of 0·000001. We may perhaps remind our readers that the susceptibility (K) is connected to the more familiar term permeability (μ) by the relationship $\mu = 1 + 4\pi K$, K being used as it is more convenient for purposes of comparison when working with what are usually regarded as non-magnetic materials.

Apparatus for use in measuring the circumferential growth of trees was exhibited by Mr. A. Mallock, F.R.S. The apparatus should be of considerable value in forestry work, especially in tropical forests, as many tropical trees do not show annual rings at all. Professor Mallock's apparatus is sufficiently sensitive to show the rate of growth at different times of the day and night. The measurements are made by means of an "invar" tape which is passed round the trunk of the tree at a convenient height from the ground, the bark having been previously smoothed with a rasp to give a good bearing for the tape. The tape passes over two rockers, and is kept taut by helical springs, one of which is attached to the end of the tape and the other to an adjustable clamp which grips the tape at an appropriate place. An arm carrying a cylindrical stud is attached to each of the rockers, and thus any expansion in the girth of the tree causes the distance between the studs to increase, the friction between the tape and the rockers under the tension of the springs being quite sufficient to prevent slipping. The movement of the studs is arranged to vary the angle between a flat glass plate and the hypotenuse face of a right-angled glass prism. Light admitted through one of the shorter faces of the prism forms interference bands, which are visible through the other face, and by the movement of these bands the growth of the tree is made apparent. The prism is mounted in a carrier, the angular position of which can be adjusted by means of a micrometer screw, and by measuring the movement necessary to bring the bands back to their original position it is possible to calculate the variation in the diameter of the tree that has taken place in the interval between the observations. The apparatus has been tried on several species of trees at Kew, and, though the rate of growth was different for each species, it was found in every case to be greater in the early part of the day than later. Actual contraction was, in fact, observed on several occasions between noon and 3 p.m.

Professor MacGregor-Morris exhibited his electrical apparatus for measuring air currents which has been previously dealt with in our columns.* It will be remembered that the apparatus comprises a Wheatstone bridge, the four arms of which are composed of platinum (or tungsten) wires heated by the passage of an electric current. Two of the wires are exposed to the air current and two are enclosed, so that the variation in resistance due to the temperature changes caused by the air current disturbs the balance of the bridge, and deflects a galvanometer in the usual way. The deflections of the galvanometer are, however, used to measure the air speed, so that the null method usually employed in Wheatstone bridge measurements of resistance is departed from. As usually arranged the apparatus is more suitable for the measurement of comparatively low velocities up to, say, 10 miles per hour, and it has recently been employed for investigating the ventilation in collieries in place of the vane type of anemometer generally used. The electrical apparatus has the advantage that the resistance wires can be placed in several different parts of the mine, and readings of the air velocity of those parts can be taken at any time, at a central indicating station. The apparatus, which is sufficiently portable to be easily carried on a bicycle, has also been used for investigating the flow of air round lighthouses, and over the edges of cliffs, it being possible to map out the course of the eddies formed in such cases.

The Royal Aircraft Establishment, of Farnborough, showed a number of instruments for ordinary use, and also for research work in aeronautics. One of the most interesting exhibits was a photographic record of meteorological readings at high altitudes. The apparatus with which this record was obtained is a stream-line casing of aluminium containing an aneroid barometer, a magnetic compass, an anemometer and a bimetallic thermometer, as well as a photographic camera. The instruments are arranged to face the camera, and a small electric lamp lighted by clockwork for periods of 20 seconds, at 2-minute intervals, gives a photographic record of the readings of all the instruments simultaneously. The film is of course moved in the interval between the exposures, so as to expose a fresh piece each time. The tail end of the casing is provided with vertical and horizontal stabilising fins, which keep it steady and always facing the wind. The compass reading thus gives a record of the wind direction, while the other instruments enable a continuous record of the wind velocity, height and temperature to be obtained. The weight of the apparatus is only 30 lb., so that it can be lifted to a great height by a kite or kite balloon. Another instrument shown, known as the "Kymograph," gives a record of the motion of an aeroplane in rolling, pitching or yawing by recording the movements of an image of the sun on a strip of bromide paper moved by clockwork mechanism. The photomanometer, also exhibited, is used for obtaining the air pressures at different parts of the surface of an aeroplane wing under various conditions of flight. It consists of a number of vertical glass tubes, containing a coloured liquid, arranged in the form of a semicircle inside a light-tight box. The tubes are connected to small pipes, the other ends of which open flush with the surface of the wing, and the different pressures at the open ends cause the liquid in the glass tubes to rise to different heights. A sheet of bromide paper is placed behind the glass tubes inside the box, and by switching on a small electric lamp in front of the tubes a shadow of the latter falls on to the bromide paper and thus simultaneously records the level of the liquid in all the tubes. Other exhibits at this stand include a liquid compass designed by the late Captain Keith Lucas, F.R.S., for use on aircraft and intended to avoid as far as possible the errors which occur when flying in a northerly course; a bubble-type sextant for use on aeroplanes which gives altitude angles with reference to a bubble instead of the horizon; and an accelerometer which records the variations of the apparent gravity on an aeroplane by photographing the movements of a fine glass fibre bent into a bow. Another instrument shown indicates the rate at which an aeroplane is climbing or descending, and we also noticed a gyroscopic turn indicator for showing whether an aeroplane is keeping to a straight course when flying in a cloud. The one other exhibit at this stand, which calls for notice, was an instrument for indicating the rate of flow of petrol. This instrument, which is suitable for flows ranging from 5 gallons to 30 gallons per hour, consists of a short cylindrical chamber containing a light vane pivoted at its axis and a fixed radial baffle plate; a groove, which gradually increases in depth, runs round the periphery of the chamber. Petrol enters the chamber on one side of the baffle plate and leaves it from the other side, moving the vane in its passage so that the area of the opening formed by the groove will be such that the pressure on each side of the vane is balanced for that particular rate of flow. The position of the vane is indicated on a dial in front of the instrument, and, by making the groove of a suitable form, a uniform scale of flow is obtained.

The two main institutions claiming our attention

* See ENGINEERING, vol. xcix, page 892, and vol. xcvi, page 178.

as to exhibits of physical, chemical and general interest are the National Physical Laboratory and the Munitions Inventions Department. The newest types of the mechanical and optical apparatus of the Metrology Department of the National Physical Laboratory made an impressive exhibit in the Archives Room on the Ground Floor; we have described these appliances on previous occasions. Upstairs three different departments were represented. Mr. J. H. Hyde showed his new apparatus for determining the absolute viscosity of liquids at high pressures; the method is due to Dr. F. E. Stanton, F.R.S., and the apparatus will appeal to the engineer.

It consists essentially of a system of four tubes, forming a closed circuit of liquid under pressure; two of the tubes are horizontal (one being a capillary) and two vertical; the upper half of the circuit contains the liquid under test, the lower half mercury. The whole system rests on a knife-edge and is supported in its horizontal position by a spiral spring. When the mercury is displaced by a certain amount a flow of liquid will take place round the circuit owing to the difference of head, and when the spring is adjusted in such a manner that the rate of extension is equal to the rate of change of mercury head, the flow of the liquid through the capillary will be under constant difference of pressure and at a velocity which can be calculated from the rate of extension of the spring. That velocity will give the required viscosity.

Mr. F. E. Smith, showed how a three-electrode vacuum tube (or valve) can be coupled in electric circuits to produce oscillations of telephone frequency. The valves, of lamp type, consist of filament (tungsten wire), grid (a nickel spiral) and plate (or a nickel cylinder). The circuit of the filament and of the plate comprises an inductance coil and a condenser; the grid is in circuit with another coil, secondary to the first, and the telephone, which the operator uses in radiotelegraphic work, is excited through a third coil from this second coil. The frequency of the oscillations is varied at will by the aid of a number of keys which alter the inductance and capacity of the circuits, and distinct musical notes are then heard in the telephone; this part of the device recalls the musical arcs of Simon and Duddell. With suitable inductances and capacities frequencies ranging from 20 up to several millions per second can be obtained. Another valve tube exhibited by Mr. Smith exemplified the glow which suddenly becomes visible in such a valve tube, containing mercury vapour at low pressure, when the current through the hot filament is gradually raised to a certain intensity. Strong signals can in this way be taken by sight, but for ordinary signals reception by telephone is preferred.

The third group of exhibits to be mentioned are the plotting chronograph of Dr. W. Rosenhain, F.R.S., and his model illustrating the phase-diagram of ternary alloys. The chronograph has been described by us; it plots directly time-temperature records in the form of "inverse rate" curves. The temperature of the metal under observation is indicated by a light spot moving over a scale, and the observer taps his key as the spot passes over successive equidistant points of the scale. The chronograph records those tappings; after a point has been recorded the drum advances one step. Thus a uniform temperature scale is produced, and the curve plotted represents the differential coefficient of the ordinary time-temperature curve. The many graphs exhibited bore evidence to the vast amount of work done with this chronograph on alloys of zinc, aluminium, copper, magnesium and silicon, and on various grades of steel. The other exhibit, the three-dimensional model illustrating the phase diagrams of ternary alloys, is a novelty. For binary systems phase-diagram can be represented by two-dimensional plane figures; in the case of ternary systems three-dimensional models are required, and they are usually made of plaster or some other plastic material. The model exhibited is built up of bent wires of different colours—each colour corresponding to one phase—representing not only the heating and cooling curves, as taken with the plotting chronograph, but supplemented by the aid of microscopic observations on annealed and quenched specimens. The complexity of phase-diagram is very suggestive of the complexity of ternary alloys—perhaps we ought to have put this statement the other way—and the model on view, about 20 in. by 14 in. by 24 in., represented only one corner of the phase-diagram of Zn-Cu-Al alloy.

The exhibits of the Munitions Inventions Department gave some very instructive information about the war-work of the Research Laboratory of this Department, which was instituted under the auspices of the Nitrogen Products Committee. We understand that the final report of this Committee has been presented to the Government and is now under the consideration of the War Cabinet, and we are glad to see that there is no desire to hold back the important results of the researches conducted which are of considerable utility to wide circles far outside the nitrogen products industry, in whose interest the researches were undertaken in the first instance. The work has, under the general superintendence of Dr. J. A. Harker, F.R.S., been carried out in three sections, and the appliances shown were the actual apparatus as developed. The novelty in the first section, the Synthetic Ammonia Section, is the apparatus for the study of catalysts, by the aid of which the behaviour of catalysts at different gas velocities, temperatures, pressures, purities is determined at pressures up to 200 atmospheres. Specimens of the several hundred catalysts actually tested by this apparatus—metals, oxides, salts, &c.—were likewise on view. Nitrogen and hydrogen are mixed in the volume ratio 1 : 3, and pass through a valve into the palladium-asbestos tubes, which are immersed in a nitre bath at 250 deg. C.; this temperature is sufficient to burn out any oxygen present in the hydrogen, thanks to the palladium. The gases then enter through a regulating valve into the catalyst-tester, which is a steel cylinder containing about 120 cub. cm. of the respective catalysts within a double heater coil of steel tubing; the gases flow down through the inner coil, up through the second coil, sweep through the catalyst, and leave outside the coils. The apparatus, which is due to Captain H. C. Greenwood, D.Sc., and was explained by Captain Nobb, has been worked for 130 hours continuously at 600 deg. C.

The great novelty in the Nitrates Section, under Captain J. R. Partington, is the direct synthesis of ammonium nitrate, free from nitrite—an undesirable by-product of the ordinary wet process—from NO and water vapour. The process starts with ammonia, which is burnt by air in contact with glowing platinum, as we have described on previous occasions. The combustion yields NO_2 and water vapour; mixed in a chamber (of capacity of a few cubic feet and provided with glass windows) in the proportion $2NH_3 + 3NO_2 + H_2O$, the gases combine directly to $NH_4.NO_3$, which condenses in a cooler to a dry white powder. The condensation is facilitated by blowing the gases against a flat surface. The resulting nitrate is said to differ from the ordinary crystallised product by several interesting peculiarities; in the presence of too much water the recovery of the nitrate is difficult.

The Hydrogen Section, under Captain E. K. Rideal and Mr. H. S. Taylor (now back to America), has dealt with the important problems of the preparation and purification of hydrogen which is equally interesting for this and the balloon industry, for the hardening of fats, and for coal gas manufacturers and others. Three-quarters of the cost of synthetic ammonia is swallowed up by the preparation of high-grade hydrogen. Before the war hydrogen was chiefly made by the action of steam on iron. The water gas process of Mond and Menger is six times more efficient, but the hydrogen so obtained is impure with CO and H_2S. Both these impurities can be eliminated by chemical means; the new catalytic processes to be explained do so at one-sixth the former cost. On leaving the meter the hydrogen (from water gas) will contain 1 per cent. or 2 per cent. of CO; this gas is mixed with a little oxygen (obtained by electrolysis of caustic potash; a slight percentage of hydrogen in this oxygen would not matter), and the mixed gases are passed through the catalyser containing iron oxide (or copper oxide and other catalysts) which is heated to 230 deg. C. by an electric coil. At this temperature, and with a large excess of hydrogen, only the CO is burnt to CO_2; the hydrogen is hardly attacked. The CO_2 is absorbed by lime water streaming through a recording apparatus which depends in its action on the electrolytic conductivity of the lime water. This kind of continuous CO_2 recorder is already used in various works, we may mention. In another apparatus the sulphuretted hydrogen is catalytically decomposed into hydrogen and sulphur. This method may prove of very high importance for gasworks, in which at present lime boxes accumulate and constitute a nuisance; so far it has only been possible to burn the carbon disulphide out of gas (by the Carpenter process). It is rather peculiar that iron oxide, apparently a very indifferent substance, should prove so useful in these reactions; how it acts, if not fully understood, but Dr. Rideal hopes to solve this problem. The water-gas hydrogen-process has the advantage over the intermittent iron-steam process that it is continuous and more easily kept under control; the catalytic elimination of CO, which may require repetition, brings the CO per centage down to 0·1, and for fat and oil-hardening and cognate industrial processes this elimination is most essential.

The Cambridge Scientific Instrument Company exhibited several instruments embodying the use of Dr. G. A. Shakespear's katharometer for determining the purity of gases. The principle is the following:—Two small platinum coils are placed in two cells, each about 1 cm. deep, 0·5 cm. diameter, the one containing the gas under test (*e.g.*, the moist air of a workshop), the other containing the standard gas (*e.g.*, dry air); the coils form two arms of a Wheatstone bridge; the resistances depend upon the viscosities of the respective gases. The coils are, in the humidity recorder, heated by a battery of 4 volts; the humidity is automatically recorded; hygrometers are not reliable in the long run. In the hydrogen-purity meter the coil is heated to 800 deg. C. and the cooling depends upon the density of the gas, all the possible impurities being denser than the hydrogen itself. The permeameter, the third instrument of this type, serves for testing aircraft fabrics. A disc of the fabric, 1 ft. in diameter (500 sq. cm. in area) is placed on the permeameter, which is a horizontal disc of gun-metal provided with concentric grooves; the space above the fabric is filled with hydrogen, which can only escape through an opening in the centre of the permeameter; this opening is closed by wire gauze, and through it the escaping gas passes into the cell block of the type mentioned. The presence of local leaks is likewise disclosed by this apparatus. The second exhibit of the Cambridge Scientific Instrument Company demonstrates Maxwell's theory of the effect of vibration of the pivot of a pendulum on the stability of the pendulum. A light pendulum is pivoted in the end of one of the forks of a tuning-fork vibrating under electro-magnetic excitation. In the one pendulum shown the limbs vibrated in the horizontal plane, in the other in the vertical plane. The pendulum at rest would hang down perpendicularly, of course. When the vibrations are excited, the pendulum was, in the first case, unstable in the vertical position, both when hanging or when standing, but stable when making a certain acute angle with the downward vertical; in the second case (fork in vertical vibration) both the vertical positions, standing up or hanging down, were stable, but the inclined positions unstable. These striking experiments were shown by Mr. Masson; when the pendulum was once rendered stable, by adjusting the electric circuit, it could be disturbed, but would return to that position.

The temperature-recording apparatus, due to Dr. G. Sims Woodhead and Dr. Varrier-Jones, of Cambridge, make use of the thread-recorder of the Cambridge Scientific Instrument Company. The instruments are also Wheatstone bridges, and give quasi-continuous records at intervals of half a minute, *e.g.*, of the body temperature of a patient; they serve also for watching temperature changes accompanying the feeding process, normal diurnal temperature variations, &c.

Dr. F. W. Aston, of Cambridge, demonstrated that the electric discharge through neon and helium tubes, apparently a continuous light column, is really striated. When examined by means of a

rotatory mirror (observed through a small telescope), the discharge is found to consist of a procession of bright (reddish or yellow) and dark bands or striations, travelling with the current from anode to kathode. The bands appear wavy, and their waviness indicates variations in speed. This waviness was more marked in neon than in helium, but the slope of the wavy lines, from which the velocity of their propagation can be calculated, was steeper in helium than in neon. The rate of propagation seems to be that of a stationary pressure wave, that is to say, the velocity of sound in its respective gas, and that velocity would be greater in helium than in neon.

Mr. C. T. R. Wilson, F.R.S., of Cambridge, whose investigation of the tracks of ionising particles through air has repeatedly been noticed in these columns, showed stereoscopic photographs of these tracks. The ionisation is caused by α or β-rays or X-rays; water is condensed upon the ions set free, and the otherwise invisible trail of the ion is converted into a sharply-defined line of cloud. Mr. Wilson's second exhibit illustrated his thunderstorm studies. The photograph showed the changes in potential during 5 minutes of the thunderstorm of June 13, 1917; a flash of lightning would cause a drop of the potential gradient through 600 volts per centimetre (in one case over 800 volts) after which the potential would gradually rise again; the moment of the perception of thunder was also recorded on his photograph.

The Meteorological Office and Sir Napier Shaw, F.R.S., personally, had a large number of exhibits which would deserve more detailed notice. There were maps exemplifying the actual pressure distribution during cyclones and the theoretical distribution, as Sir Napier explained in the Royal Institution last year; five little maps, showing the stream function of the air for levels up to 10,000 ft. in the night of October 19–20, 1917, when a fleet of Zeppelins was destroyed by high winds. On the surface the wind velocity did not exceed 10 miles, high up it probably reached 90 m.p.h. Illustrations of many other weather studies made during the war; apparatus (theodolites and others) for watching air currents with the aid of quite small balloons; the barothermograph of Major Gordon Dobson, mounted so as not to be disturbed by the vibrations of aircraft; magnetic records from Eskdalemuir, and many other features, comprising a great variety of beautiful cloud photographs were exhibited. A modification of a lightning recorder, consisting of an aerial on the building, inductively coupled with a coherer (of the old metal filings type with decoherer) and a recording apparatus was also on view.

The demonstrations of vibrations, forced and coupled, by Professor E. H. Barton, F.R.S., and Miss A. M. Browning, were described by us last year, when Professor Barton lectured at the Royal Institution. New was the series of pendulums to illustrate the ordinary octave of musical instruments; the lengths of the pendulums were increased in geometrical progression so as to correspond to the actual intervals between the successive notes.

The detection of defects in aeroplane timber by X-rays was the subject of one of the evening discourses, delivered by Major G. W. C. Kaye; we noticed the paper on these tests by Major Kaye and Dr. R. Knox, in our report on the recent discussion of these problems by the Faraday Society and the Röntgen Society. The radiographs of large carbon electrodes (up to 22 in. diameter) for steel-smelting furnaces which Sir Robert Hadfield, Bart., F.R.S., showed on the same occasion, were likewise on view; Sir Robert had the radiographs conveniently arranged for stereoscopic study with the aid of a rotating mirror.

The Army form of apparatus for continuous oxygen administration in cases of gas poisoning was exhibited by Dr. J. S. Haldane, F.R.S. A small bag is attached to a face-piece; by a reducing valve and a graduated tap a constant stream of oxygen is delivered into this bag, which is emptied at each inspiration; none of the oxygen being wasted, its consumption is reduced to a minimum, and the oxygen administration can be continued for days. How chronic cases of gas poisoning are treated by continuous oxygen inhalation in hospitals was explained by two models from Mr. Joseph Barcroft, F.R.S. The one model represented three wards, each built up of glass, as established in the Cambridge Physiological Laboratory; the patient is placed in these glass rooms for five days, being allowed out for 7 hours per day for taking exercise, &c. The second model showed the oxygen chambers of the North Staffordshire Infirmary, which is under the supervision of Dr. Shufflebotham. The Director of Research, Air Ministry, exhibited two liquid oxygen containers, made of vacuum-jacketed spherical copper vessels of the kind mentioned by Sir James Dewar in his Royal Institution discourse last January.* The big container shown has a capacity of 50 lb. of oxygen, weighs full 80 lb., empty 30 lb., and uses about 2 lb. or 2¼ lb. of oxygen per day; it was made by Messrs. J. Levick, of Birmingham. The small container, made by Messrs. Hinks, also of Birmingham, is a vaporiser flask for aircraft, weighing fully charged 25 lb., the capacity is 5 litres, which means 3,500 litres of gas, and the loss amounts to 1 lb. of oxygen per day. Charcoal is placed between the two copper walls of the vacuum jacket.

The "Mineral Yeast" of Mr. A. Chaston Chapman, F.I.C., is of a high peculiar interest. It became known during the war that a human food—the so-called mineral yeast—was made in Germany to supplement the bread rations, and it has since been ascertained that there are five factories of this material in Berlin alone and several others elsewhere. Some information appeared in the technical journals; Mr. Chapman worked out the rest. The organism in question—apparently a *mycoderma*, but not quite identified yet—is capable of taking up the whole of its nitrogen from ammonium salts, and building up protein and fat from mineral salts, which the human being and ordinary animals cannot do; we have to be fed on albumenoid substances. Whether the organism of Mr. Chapman is identical with the German mineral yeast is not quite certain; but his product has very remarkable properties. It contains 50 per cent. of protein, 5 per cent. of fat, and has a pleasant taste like cream cheese; it has no bitterness, and does not ferment into alcohol. It is not a true yeast, *i.e.*, it does not belong to the *saccharomyces*. It grows freely on nutrient solutions, and at a temperature of 38 deg. C. a full crop of the substance is obtained within a day or two; it can even be produced at ordinary temperature, and the thick, crinkly white film, exhibited by Mr. Chapman, had indeed been raised at an ordinary temperature. The raw materials required for the production of this mineral yeast are glucose, ammonium salts, some phosphate and small quantities of potassium and magnesium salts. The original start was made with molasses; in their absence sawdust, inverted into sugar in the ordinary way, will answer. The production of the substance in Germany is said to be continued for making cattle food.

As regards biology, zoology, botany and physiology, we can only mention two of the many exhibits. The first is also of curious interest, frogs and tadpoles obtained by artificial parthenogenesis, shown by Messrs. E. S. Goodrich, F.R.S., and A. T. Coventry. The method was first used by Professor E. Bataillon in 1910. Unfertilised frogs' eggs are removed from the oviduct and pricked with a fine glass needle; some 80 per cent. of the eggs thus treated undergo cleavage, but only a much smaller number pass into the embryo stage, and very few develop into tadpoles and frogs; two such tadpoles were swimming about in their glass basins, exemplifying the possibility of parthenogenesis at any rate. Dr. R. T. Leiper gave demonstrations of the experimental transmission of bilharzia infections of man; he discoursed on the subject in the second lecture of the evening. Bilharzia is an affection of the intestines and bladder caused by worms, from which half of the population of Egypt suffer, and which was studied during the war. The infective stage enters through the skin.

Astronomical exhibits finally were not particularly conspicuous. The Royal Astronomical Society showed beautiful photographs of stellar nebulæ taken with the 72 in. reflector (an instrument of which we hope shortly to give a full account) of the new Observatory at Victoria, British Columbia, by Mr. J. S. Plaskett; the ring nebula in Lyra appears on one of these photographs. Professor H. E. Newall, F.R.S., displayed Dr. G. E. Hale's remarkable photographs of the Zeeman effect in sunspot spectra, and the Solar Physics Observatory of Cambridge — at which Mr. Wilson's thunderstorm observations are made — showed photographs of the spectra of Nova Aquilæ (of June 13, 1918) and of other new stars.

* See ENGINEERING, page 117, *ante*.

PERUVIAN MINING.

THE Peruvian mining industry continued in 1917 to occupy the excellent situation to which it had attained during the preceding year, notwithstanding the fact that the conditions which prevailed were less advantageous. Some of the principal mineral products, such as copper, molybdenum, silver and lead reached in 1917 higher prices than those obtained in 1916; others, of much less importance comparatively, including antimony, tungsten and vanadium, sold at lower rates than those of the preceding year. On the other hand, a notable feature which greatly influenced the general results for 1917 was the very great increase in the cost of production and of transport, whilst depreciation in bills of exchange and the prohibition of gold exports from Europe and the United States further affected the mining markets. These statements are taken from the Report No. 95, for the year 1917, recently issued by the Corps of Mining Engineers of Peru, which gives the total value of the mining output for the country from 1903 down to the year under consideration. The figures are given in Peruvian pounds, which we take as equivalent to pounds sterling, and abstract as follows: 1903, 1,382,080*l.*; 1913, 4,495,758*l.*; 1914, 4,169,307*l.*; 1915, 5,929,845*l.*; 1916, 8,656,178*l.*; 1917, 9,234,160*l.* The latter total is the highest ever reached.

The copper industry is the most important of Peru by the amount of capital invested in it, the value of its output, the number of operatives it employs and the revenue it yields to the State. It amounts in value to the third of the country's total exports. In 1917, the output amounted to 45,176 tons of fine copper having a commercial value of 5,059,000*l.*, as against 43,078 tons and 4,800,900*l.* in 1916. The greater part of the Peruvian copper, 93·28 per cent. of the total, is produced in the department of Junin, where the plant at the American Cerro de Pasco Copper Corporation is located. This corporation has practically the monopoly of the copper output. In 1917, Peru occupied the fifth place in copper production, being preceded by the United States, 856,570 tons; Japan, 124,306 tons; Chili, 75,345 tons; and Canada, 50,351 tons.

In importance as a mining product, petroleum follows directly after copper; the value of the output in 1917 was 1,651,174*l.*, and the industry shows signs of great developments in the future. Of the 867 wells yielding petroleum in 1917, six had been drilled over twenty years ago, 15 had been in activity for over eighteen years, whilst 50 had been working for just over one year, and 61 for less than one year. In 1917, 115 new borings for petroleum were driven, of which only 19, or 16·5 per cent., were unproductive. The Report from which we quote states that natural gas is utilised to a very limited extent only in the petroleum districts, although the volumes of this commodity which might be turned to account are considerable. The companies do not exercise sufficient control over the output of their wells as is shown by the fact that large quantities of oil are used as fuel for work in which the application of natural gas would be most advantageous. In the year 1917, 67 per cent. of the total yield of crude petroleum was refined. The total quantity of crude petroleum refined was 240,068 tons, as against 263,767 tons in the preceding year. These quantities cannot be largely increased for the present, owing to the comparatively low capacity of the two only refineries existing in the country. These are situated at Talara and Zorritos, where are located storage tanks and factories for making the casks for conveyance of the products.

In 1917, Peru produced 337,928 kg. of silver, of a value of 1,641,205*l.*, as against 335,529 kg. and 1,332,249*l.* in 1916. The exceptionally favourable conditions of the silver market in the year under

review led to the hope of a more appreciable increase in the production than the one which took place. Prices remained very high, reaching figures which had not been attained since 1878, the average price for 1917 being above those quoted during the last quarter of a century. Notwithstanding this, the increase in output over the preceding year was only 2,399 kg., or 0·7 per cent., which may be attributed mainly to the fact that the silver mines are generally privately owned, or in the hands of small companies, who have not the means to give a strong impulse to their working; the adverse factors outlined above had also their influence in regard to this metal. The increase in value, 23·2 per cent. was due to the high price of silver; if this high price continues to rule, as financiers and experts believe, it is thought probable that the Peruvian production will increase on a larger scale during the following years. The department of Junin, which is at the head of the list in regard to copper, also heads the list in the matter of silver, its proportion being 67·77 per cent. of the total output.

After silver there follow, in order of total value of output, vanadium, 4,083 tons and 247,138*l.*; gold, 1,887 kg. and 244,928*l.*; and coal, 353,595 tons for 202,313*l.* In regard to this latter mineral, there is an increase of 34,532 tons and 43,624*l.* over the figures for 1916, which bears mainly on two collieries belonging to the Cerro de Pasco Copper Corporation, the output of which was intensified in conjunction with the greater metallurgical activity of this concern. Circumstances in the course of the year under review, adds the Report, have shown the urgent necessity of starting a national coal extraction industry on a large scale, both to relieve the country of a constantly increasing tribute paid to foreign nations for a mineral product which is encountered in abundance in the country itself, and to stimulate the development of other products, progress in regard to which frequently depends mainly upon the availability of a cheap fuel. These considerations have led the Peruvian Government to investigate the coal basins throughout the country and to deal in the first place with those in which the working would be easiest. Lines of access are being investigated at the same time. The output of coal for 1917 was the largest recorded for any year. The figures for 1903 were only 36,920 tons, for 51,688*l.* The total output for 1917 consisted of 341,288 tons of bituminous and semi-bituminous coal, 8,131 tons of asphaltite and 4,176 tons of anthracite.

Next in order of value follows tungsten, the output of which was just over 406 tons of concentrates, having an average grade of 63 per cent. of tungstic acid and a value of 104,349*l.* Compared with the figures for the preceding year, those for 1917 show a decrease of 117 tons in quantity and of 113,434*l.* in value. The importance of this latter figure is explained by the lower prices obtained for this mineral in 1917 as compared with those ruling in 1916. In 1910, the production was 12 tons, of an average grade of 72 per cent., and valued at 1,150*l.*

Among the other mineral products of Peru may be mentioned lead, 1,272 tons, valued at 29,308*l.*; antimony, 902 tons and 16,254*l.*; molybdenum, 7 tons and 4,309*l.*; mercury, 1,500 kg. and 750*l.*; bismuth, 1,357 kg. and 706*l.* No zinc bearing minerals of a grade suitable for commercial treatment were mined in 1917, but the Report states that such minerals, having a yield of 14 per cent. of zinc and 0·320 kg. of silver per ton are known to exist in large quantities.

The men employed numbered 19,003 in the mines and 4,735 in factories, a total of 23,738, or about 1,000 more than in the preceding year. The working day in the Peruvian mines is generally of ten hours, except in cases where the rapid driving of a heading is required, when three shifts of eight hours each are worked. The men are paid generally monthly but each week checks are granted them at their request for household expenses.

THE CERAMIC SOCIETY.

THE spring meeting of the Ceramic Society was held on Thursday and Friday, May 22 and 23, at the Hall of the Literary and Philosophical Society, Middlesbrough, when Sir W. J. Jones, Deputy-Controller of Iron and Steel Production, Ministry of Munitions, presided over a large gathering of members hailing from the London and Glasgow districts, Wales, Lincolnshire, and many intermediate localities. On behalf of the civic authorities, the Mayor of Middlesbrough (Mr. Joseph Calvert, J.P.) offered a hearty welcome to the visitors, and this was echoed with equal cordiality on behalf of the Tees Conservancy Commission by Sir Hugh Bell (chairman) and Mr. John H. Amos (general manager).

The business proceedings on the 22nd inst. opened with a paper by Mr. J. B. Atkinson, M.Sc., and Mr. J. T. Stobbs, F.G.S., which was read by the former, on "The Geology of the Refractory Materials of the North of England." Firebricks are said to have been made first on the Tyne about 1764; in 1838, 7,000,000 firebricks were made in a year, and in 1863, 80,000,000, besides a large number of retorts. Coke ovens were first mentioned as used in this district in 1763. In 1888, 48,200 tons of pig-iron were made by the use of coke.

Most of the refractory materials in the North of England are derived from the Carboniferous System, mainly from the Coal Measures, but to some extent from the Millstone Grit and the Carboniferous Limestone Series. Some silicious rock is obtained from the Lower Oolite in the Commondale district of North Yorkshire. The Permian of Durham furnishes some dolomite.

In 1913, 27 per cent. of the output of fireclay for the British Isles came from the North of England. Fireclay forms the immediate pavement of most coal seams, but it may also occur as a band in a seam of coal, sometimes as the roof, and occasionally not directly associated with a coal seam.

Fireclays are believed by many geologists to represent ancient and exhausted soils, compounds of iron and alkalies having probably been extracted by the vegetation, and the clays thus made more refractory. The fireclays in the Northumberland steam coal district, unlike those in the Northumberland and Durham coking coal districts, are not much used. Steam coals have vertical sheets, and some times horizontal plates, of white spar, from which the coking coals are practically free.

The chief differences between ganisters and sandstones are the finer grain size and more silicious cementing material of the former. Descriptions were given in the paper in some detail of a number of important deposits of fireclay, ganister, &c.

The next contribution was a paper by Professor P. G. H. Boswell, on "Mica Schist for Lining Cupolas and Steel Converters." This had reference to the use of such material in the United States, the rock being easily split and worked into shape. It is built in as a lining to the firebrick casing. It is suggested that apparently similar materials occurring in Scotland, &c., might prove serviceable in a similar way. Discussing the paper, Dr. A. Scott mentioned that it was on record that material of the same general character was used in Sweden as early as 1740, and also later. It has also been employed in other countries.

The next paper, by Mr. W. J. Rees, was on the "Corrosion of Coke-Oven Walls. I. The Salts Extracted from Coal by Washing." Results of analyses of water and of solid residues from the evaporation of drainage water from washed slack hoppers, and also of unwashed and washed slack, show that sodium sulphate, as well as sodium chloride, is removed from the coal by washing. The pit water used in the washing contains a good deal of these salts in solution, but the gain by using purer water would not be likely to be worth the expense. The rate of flow of water through the washery is possibly of greater importance. Sodium sulphate would react with hot coal to form sodium carbonate, and this would have corrosive action on the coke-oven walls. Dr. Mellor suggested that water containing particular substances in solution might prove more effective in washing the coal than the water used by Mr. Rees.

In the next paper, Mr. G. R. L. Chance presented "Some Criticisms by a Firebrick Manufacturer." According to his experience, the success of a business depends on: (1) The efficiency of the sales department, (2) cheapness or economy in cost of production, and (3) the quality of the finished product, and in a firebrick business the last is much the least important, providing the quality is not decidedly below the average.

Users are not always clear as to what they want, ordinary quality or special quality, and when the latter is really required they seem loth to pay the extra price. Often also special firebricks are ordered under a time limit for delivery, which is inadequate for ensuring the best results. As regards blast-furnace linings, tight joints could be ensured by the use of a carborundum wheel to remove slight imperfections of shape, a plan adopted in Germany for finishing certain bricks. Users, Mr. Chance stated, could help firebrick manufacturers by giving information about failures, and by testing bricks in actual use. The question of the best kilns for burning firebricks is very important, and as fuel economy is a national question, a thorough investigation is highly desirable. Another subject which should be tackled immediately is the standardisation of patterns, with a view to reducing the comparatively heavy cost of tools, and dies (especially of sleeves, stoppers and nozzles), as well as facilitating substitution when necessary.

Dr. Alexander Scott next read a paper entitled "Factors Influencing the Properties of Silica Bricks (Part I)." This gave the results so far of an investigation of the effects of various bonding materials on the inversion of the quartz to the high temperature forms and on the properties of silica bricks. The properties here considered are specific gravities, porosity after-expansion and refractoriness. The silica rock used was a fairly pure vein quartz, and the bonding materials used included lime, magnesia, alumina, iron oxide (with or without carbon), titanic oxide, lime mixed with magnesia, alumina, iron oxide (with or without carbon), or titanic oxide respectively, magnesia mixed with alumina or with iron oxide (with or without carbon), lime mixed with iron oxide and titanic oxide, and also Glenboig fireclay and China clay, used separately. Except as regards the last three, ordinary laboratory chemicals were used. Of the simple oxides 2·5 per cent. was used, of two oxides together 1·25 per cent. of each, and of the three oxides (lime, iron oxide, and titanic oxide) 1 per cent. of each. Ordinary charcoal was used for the carbon, 0·5 per cent. and 0·25 per cent. with 2·5 per cent. and 1·25 per cent. of iron oxide respectively.

Of the simple oxides, lime or magnesia cause the greatest conversion of quartz, this being increased when iron oxide is also present, and to a less extent by the addition of alumina instead of iron oxide. Lime usually has more influence than magnesia. Iron oxide alone induces a high conversion, but alumina alone causes a low conversion. The conversion is generally greatest where bonding material forms a relatively fusible mixture with the fine-grained silica of the matrix. The conversion can be considerably increased by raising the firing temperature.

The specific gravity (both true and apparent) mostly tends to vary directly as the firing temperature. The true specific gravity may be taken as giving a qualitative idea of the amount of conversion, but the quantitative relation is only approximate.

The porosity varies irregularly with the firing temperature when the simple oxides, lime, magnesia, alumina and iron oxide, are present singly. The variation is regular with lime and alumina or titanic oxide, with alumina and magnesia or iron oxide, or with magnesia plus iron oxide and carbon. A corresponding grouping occurs in connection with the apparent specific gravities.

After-expansion depends on the duration and temperature of firing. The results obtained with test pieces fired at cone 26 gave practically identical values for the true specific gravity, and as these approximated to the specific gravity of cristobalite, most of the quartz was converted. Hence it seems that the after-expansion at cone 26 is indicative of the total expansion of the material during conversion. Two different bricks—with lime and alumina, and with lime, iron oxide, and carbon, respectively—after heating to cone 16, showed very similar expansions; when heated to cone 46, that of the former was nearly twice that of the latter. In like manner, the after-expansion at cone 16 with lime alone is much higher than that with alumina alone,

but the expansion of the latter at cone 26 is much greater than that of the former. The discrepancies of course depend on the different rates at which different bonds induce conversion, the rate in each case depending on the temperature. The important point is to determine the total expansion, so the brick should be tested at a temperature which will give nearly total conversion within a comparatively short time, and in the case of the bricks under consideration, cone 26 is high enough. To avoid spalling, the heating and cooling must take place slowly.

The smallest expansions were found in bricks with lime plus iron oxide as bond, and the next lowest with these oxides used separately. Magnesia gives higher expansion than lime, when used alone, and also with combinations of these with alumina and iron oxide. Alumina or titanic oxide gives a high value, which is much lower in either case when another oxide is also present. The fireclay bond gives low expansion. The presence of carbon does not greatly alter the after-expansion, but in three of the four cases tried, the bond containing carbon gives slightly lower values than the corresponding carbon-free bond.

With reference to refractoriness, in the case of blocks containing lime or magnesia (with or without other bonding material) the softening is due to the fusion of the mixture of silicates and fine-grained free silica in the matrix. With alumina or iron oxide, or both, as bond, the matrix and rock fragments seem to fuse simultaneously, and the softening point of the piece is practically the same as that of silica. The absence of squatting is due to the high viscosity of fused silica. Fireclay acts in a very similar way.

Dr. J. E. Stead, F.R.S., next read a "Note on a Silica Brick from the Roof of an Open-Hearth Furnace." From a number of analyses and tests the following general conclusions were drawn: That fusible silicates formed at the exposed surface of the brick largely flow upwards by capillary attraction to cooler though still very hot parts of the brick, part of the lime, alumina, and iron oxide, being removed from the superficial parts of the brick with a relatively smaller proportion of silica. The iron oxides are at a maximum in the black or dark grey zone adjoining the lower zone exposed to the flames, but the adjoining zones below and above also contain considerable quantities of iron oxides carried by the fusible silicates, and these three zones have much less porosity than the fourth or upper zone, which corresponds to the original brick, being practically unaltered. The specific gravity of this upper zone corresponded closely with the average of standard silica bricks (1·77 against 1·75). Shortening of the bricks through fluxing action of the floating dust causes the fusible silicates in the intermediate zones to move upwards, with the result that the fusing point of the newly-exposed superficial portion will be raised, an arrangement which extends the life of the brick. The ferruginous silicate surrounding the silica grains (tridymite) could not have been in a freely molten condition at about 1,700 deg. C., the temperature of the superficial parts of the brick. The specific gravity of powdered material from the lower or superficial zone, viz., 2·338, indicated a complete change of the quartz into tridymite. The results of the investigation substantially confirm results obtained independently by Mr. E. Rengade and Mr. C. S. Graham.

In the course of a short discussion, Mr. Cosmo Johns stated that the presence of magnetite rather improves the bricks, but that no chemical action whatever takes place between magnetite and silica. Mr. E. A. Coad-Pryor read a paper by Dr. W. Rosenhain and himself on "A New Type of Recuperative Furnace." Mr. H. M. Ridge stated that a very similar furnace had been in use for some time, on a fairly large scale. We publish the paper by Dr. Rosenhain and Mr. Coad-Pryor in full on page 702 of the present issue.

At the meeting held on Friday, the 30th inst., a paper by Mr. W. J. Rees, F.I.C., entitled "Specifications for Refractories for Glass Works' Use," was read. This comprises introductory remarks, followed by provisional specifications, recommendations, and suggestions relating to tank blocks, raw clays and grogs, &c.

It is laid down that the analysis of raw clays and grogs shall show content of SiO_2, Al_2O_3, K_2O, Na_2O, TiO_2, CaO, MgO, Fe_2O_3, and the loss on ignition. Dr. Mellor pointed out that BaO is an important binding agent often present in ganisters.

With regard to the suggested limits for composition and fusion temperature for three grades of raw clays, Dr. Ormandy, who had some years' experience in a St. Helens glass works, expressed the opinion that it was hardly possible to comply with grade I requirements with the materials now available.

The next three papers, owing to shortness of time, were taken as read. Dr. A. Bigot's paper, entitled "Practical Guide for Manufacturers of Silico Products," was confined to topics of practical interest including the choice of raw materials and the most rational and economical processes of manufacture. Mr. J. C. Thomlinson's paper was on "The Glazing of Refractories." Mr. J. A. Audley's paper, entitled "Further Notes on Zinc Furnace Refractories," was supplementary to the paper read at the Swansea meeting. It deals largely with the slagging and glazing of zinc retorts, but also gives further analyses, &c. Incidentally it is mentioned that the mixture used for making furnace bricks from St. Louis clay consisted of 40 clay to 60 grog. It was also mentioned that the difficulties in applying a coating of zirconia to the distillation vessels might be obviated by using mixtures with progressively larger proportions of zirconia, finishing with the latter alone.

Mr. Cosmo Johns, the chairman of the committee, explained the report on "The Standardisation of Tests for Refractory Materials (Part III)," relating to the penetrative action of slags. Three methods for investigating this are described and illustrated in the report. As a personal suggestion, he advised the use of slag of definite composition made from pure materials—as used by Dr. Scott in his research on silica bricks—rather than ordinary commercial materials.

The British Refractories Research Association can now be registered and start working, the report of the committee having been adopted by the Ceramic Society. It must be remembered that it is not a trading society. Members will be firms and companies, as well as individuals, who are interested in refractory materials and products in any way, and the association is to be managed by a council elected annually by the members, on a very wide basis. Dr. J. W. Mellor, of Stoke-on-Trent, is to be the technical director of the research work, and Mr. R. C. Rann has been appointed secretary, the offices being in London. Members are to contribute annually 5 to 50 guineas for five years, and their only other liability is 5*l.* per member towards liquidation in case of winding-up during the period of membership or within one year afterwards. The Scientific and Industrial Research Department will contribute for five years an amount equal to that contributed by the members. The total sum required is estimated to be about 6,000*l.* per annum, but if more should be available it will simply mean that more research work can be proceeded with accordingly. Co-operation with similar research associations in other industries will be aimed at.

Members will have the valuable privileges of getting answers to technical questions, of recommending subjects for research and the right to use any patents or secret processes resulting from the research work of the association. It may be added that over 500 guineas per annum for five years have already been promised. A preliminary programme of research work has been formulated, and it is proposed to have refractories made to the association's specifications, and to have them tested under service conditions.

Sir J. William Jones was elected President of the Ceramic Society, and Messrs. W. Hamilton, D. Sillars, Whiteley and Dr. McCance were added to the list of vice-presidents. Messrs. G. V. Evers, Cosmo Johns and Cyrus Jones were elected new members of the council.

NOTES.

WATER POWER IN JAPAN.

THAT our Asiatic ally is fully cognisant of the industrial value of water power may be gathered from the fact that a sum of 830,657 yen (85,000*l.*) has been set aside for the purpose of investigating sites for hydro-electric power plants, and for collecting reliable data for use in connection with future hydro-electric undertakings in Japan. The expenditure will be distributed over five years, and the report of the work done during the first year, 1918, has just come to hand. During the year the staff and employees have been appointed, and the necessary regulations and the general scheme for the work, have been prepared. The country has been divided into five districts, to which a total of 22 surveying parties are att[illegible]d a general reconnaissance of the principal ri[illegible]h district was commenced in June last. T[illegible]r gauging stations and meteorological obse[illegible]ave been selected, and, in some cases, th[illegible]ave been constructed and a start made with [illegible]surement of the flow. In this connectio[illegible]ever, it is interesting to note that the conditions in Japan with regard to labour and materials must be very similar to those now existing in this country. We are led to this conclusion by the statement, in the quaint language of the translated report, that "the survey was not a little prevented from rapid progress" because of the extraordinary rise in wages and in prices of materials. The programme of work includes the selection of 635 power sites, and the setting up of 320 gauging stations and 166 new meteorological observatories. These are to be completed at the end of September next. The only sites to be surveyed, at present, are those where more than 1,000 h.p. can be obtained by economical exploitation. Hydro-electric power plants in Japan already utilise rather more than 1,000,000 h.p., and a further 2,000,000 h.p. is under lease for exploitation. About half of the latter quantity is now being developed, and it is estimated that some 5,000,000 h.p. is still capable of being developed on commercial lines.

WIRELESS TELEPHONY AND DIRECTION FINDING.

Among the matters which showed great development during the war, but which for military reasons were not brought before the public, wireless telephony must take an important place. That this matter has advanced to an entirely practical level, as far at least as clarity of speech is concerned, was demonstrated by Marconi's Wireless Telegraph Company on the 28th inst. During a demonstration carried out on that day a "National" steam omnibus, equipped with receiving apparatus, set out from the company's works at Chelmsford and ran to Colchester. The 'bus, during the whole run, was able to pick up telephone messages from a sending station at Broomfield, some 4 miles north of Chelmsford, while telephone conversations between Broomfield and Marconi House in London could be heard perfectly. The receiving station was naturally a far from ideal one, being mounted on a moving omnibus, and the noise of the vehicle interfered a little with the clearness of speech. When the 'bus was standing, however, the messages were clearer than one is used to obtaining as a general rule over the ordinary telephone system. The distance speech was transmitted from London to Colchester is somewhat over 50 miles. The demonstration was concerned not only with wireless telephony, but with direction finding by wireless. To demonstrate this possibility the omnibus already referred to was directed to a position some mile or so from Colchester, which was not selected by, and was unknown to, the Marconi Company's officials. A field wireless set, which accompanied the 'bus on a motor van, was then set up and signals were sent out. These were picked up by receiving stations situated at Chatley and Heybridge, which are each some 8 miles to 10 miles from Chelmsford and some 10 miles apart. These stations, in conjunction, then worked out the position of the omnibus set and telephoned the information to the party there. The position given was correct to within some 150 yards, the distances from the receiving stations being about 20 miles in each case. Position finding of this kind is, of course, carried out by obtaining the intersection of lines of direction from two stations at either end of a base. We understand that such directions can easily be measured correctly to within 1 deg., and that in

skilled hands correctness to within half a degree is achieved. The principle of direction finding is the employment of two vertical closed circuits fixed at right angles to each other and acting as aerials. Impinging waves meeting the circuits at different angles affect them differently, and as the circuits can be swung round their vertical axes a position of balance can be obtained, and so the direction of the source of the waves determined. The currents induced in the circuits are amplified and rectified by a valve which is in effect a combined transformer and rectifier. This valve is also used in connection with the wireless telephone and is, in fact, the essential feature which has made both processes possible. In the telephone a variation is impressed by a telephone transmitter on to a steady high-frequency current which is generated by an ordinary wireless arc-generator or an oscillating valve. It is obvious that the direction finding apparatus should prove of great value in connection with shipping and aeroplane work. A ship properly equipped could work out her position in a fog from messages received from any two wireless stations the positions of which were known.

GERMAN TEXTILE INDUSTRY AND AMERICAN COMPETITION.—At the general meeting of a Cotton-Spinning and Weaving Company in Augsburg much apprehension was expressed on the subject of American competition, and several measures were passed as a safeguard against it. It was decided that all members of the Board must belong to Germany, having fixed domicile there, and also that the rule should not be altered or other matters affecting the independence of the company decided without the consent of nine-tenths of the voters present at a meeting. This particular company was in a fairly good position owing to its extensive employment of water power and also to a sound financial policy. Surprisingly low offers from abroad are already in the market, and it was thought more than likely, that America would not only want to supply raw materials, but would also force her way into German industry by means of American capital. The import of cotton, it was said, would have to be subject to several years' credit. This might be arranged either by the whole German industry combining under the auspices of the State, the combine then offering the American banks any available securities, or the different concerns would have to make their own arrangements independently.

IRON OR STEEL PIPES FOR HOUSE DRAINAGE.—In order to decide on the merits of house drainage pipes of cast-iron, wrought-iron and steel and of their joints, &c., Eng. W. Paul Gerhard, of New York, collected material in 78 of the principal buildings of Broadway, confining himself to buildings of six and more storeys, and of more than five years of age, since more recent buildings would not afford much information as to corrosion. Thirteen of the buildings were over 30 years old, only six less than 10 years. In the older buildings cast-iron predominated, in more recent buildings pipes of steel and wrought-iron of the screw-jointed type (not caulked). Particular attention was paid to the roof vent pipes, as they were likely to show the greatest natural corrosion; of the 1,076 vent pipes examined, one-third were cast-iron. The tests on which Gerhard relied in his distinction of steel and wrought-iron and as to other features were the following:—In the fracture test the pipe was hammered to the point of fracture; genuine wrought-iron should give a dull gray fibrous fracture; steel an even, bright, crystalline fracture; the zone of galvanised steel peels off in scales under the hammer, whilst it should stick to wrought-iron without cracking. In the threading test a thread was cut in the pipe; a wrought-iron pipe should give crumbling chips, steel a long spiral. Owing to corrosion wrought-iron becomes pitted and pock-marked; steel scaled off: cast-iron also cut uniformly. In the acid test the specimens were cleaned of grease and scale and then placed for 15 or 20 minutes in a cold mixture of water, sulphuric acid and hydrochloric acid in ratio 9:3:1; the fibrous structure of wrought-iron then should come out, whilst steel should dissolve uniformly. For the manganese test a chip was dissolved in warm picric acid, and to the cooled solution drops of sodium bismuthate were added, until a brown precipitate appeared. the pinkish colour of the solution then indicated the presence of manganese which would be characteristic of a steel; wrought-iron should not give a pink solution as manganese is not used in its preparation. This test, Gerhard admits (Journal of Franklin Institute, January, 1919), may be misleading; his other tests might also be questioned perhaps, but he submitted doubtful cases to further tests. Finally, he performed a microscopic test after etching the specimen with picric acid; wrought-iron would then show fibres of silicate slag, whilst steel would show pearlite in fairly even distribution. From his investigations he concluded that cast-iron is satisfactory from the corrosion point of view, but unsatisfactory with respect to the caulked joints which are apt to turn leaky. Direct joints are superior, provided the pipe could be well screwed into the shoulder of the fitting; exposed portions of the thread should be protected against external corrosion. As regards steel and wrought-iron pipes, genuine wrought-iron appeared undoubtedly the more durable material.

DRAUGHTSMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—There is one sentence in Mr. Walker's letter in your issue of 23rd inst., which whilst true in itself, undoubtedly will lead to false inferences by your readers, inferences which, as honest controversialist, Mr. Walker should have taken means to safeguard against. The sentence as it stands, without qualification, reads: "The editor of the *Draughtsman* is appointed by the Representative Council, is not controlled by the Executive; nor responsible to them for the trend of his writings." The reference was absolutely gratuitous, as the controversy in your columns centres round the proposed affiliation of A.E.S.D. to the Labour Party, "Scrutator's" actual phrase being: "One would think that the primary object of the A.E.S.D. was to help to revive the rather doubtful fortunes of that Party, whose banner is the red flag, and whose war-cry is class hatred."

The irony of the matter, so far as I have been introduced into the controversy, resides in the fact that as an individual member of the A.E.S.D., I have hitherto opposed this affiliation, and as editor of the *Draughtsman*, interpreting the adverse decision of the December Conference, have editorially opposed it. Indeed, the controversy in the columns of the *Draughtsman* arose out of a letter to the editor from Mr. Walker, in which the latter attacked my attitude of antagonism to this particular proposal. I took practically no part in the further debate, but left the correspondence columns open to the protagonists of the opposing schools, believing that free and open discussion can only serve good ends, and that editorial interference was undesirable.

Yours faithfully,
GEO. W. THOMSON.

263, Maxwell-road, Pollokshields, Glasgow,
May 26, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—If "O.L.D." will compare the closing sentences of his and my letter, he will find, by an odd coincidence, that they are intimately related. It is difficult to see why valuable space in ENGINEERING has been occupied by this controversy at all. If my anonymous critics are loyal members of the Association they should realise the undesirability of washing our dirty linen in public. We have a wash-tub of our own, called the *Draughtsman*, where "Scrutator" can exercise his heavy irony at pleasure, and where the simple pathos of "O.L.D." may bloom perennial. Sweet are the uses of adversity, and if these nameless gentlemen—these vague shadows of an industrial antiquity—will but avail themselves of opportunities which a paternal (and democratic) Association has provided, we shall not have puzzled over their identity in vain. Nowhere will their sorrows find a better resting-place, for the editor, though fierce in his convictions (as all editors should be), is tender at heart (as all editors are). And the Control Scheme is quite all right. We got more than the 80 per cent. voting, and if instead of 95 per cent. in favour we only got 93 per cent.—well, the Representative Council, anticipating the protests of "Old Scrutator," saw that the policy of the Association ought not to be dictated by a small minority. I am, Sir,

Yours faithfully,
ERNEST H. WALKER.
(*Chairman, Executive, A.E. & S.D.*)

May 26, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—The reference by "O.L.D." to the action of the A.E.S.D. regarding the Control Scheme at once finds him as one of that small body unthinking, but by no mean, inarticulate, critics of whom there is usually one specimen in every large drawing-office. He states that the Representative Council, having failed to obtain the desired majority on the recent ballot, is trying to push the scheme through by other means. Personally I take the trouble to read my ballot paper, and I, therefore, know that the extraordinary figures specified (by which less than 5 per cent. of the members voting against would be sufficient to stop the scheme) were declared by a desire to operate the scheme as an agreed measure made effective by the personal pledges of the members, and not by force of rules. The proposal now being discussed by the branches is to make the scheme a part of the rules. I should like to point out that it was quite competent for the Representative Council to do this in December, 1918, but, although they were fully in favour of the principle of the scheme, they preferred that the matter should be more fully discussed by the members as the alteration to rules could not be undertaken until December this year, and the ballot was called for with the object of operating the scheme before that date. Incidentally, the ballot has shown an overwhelming majority in favour of the scheme, and if "O.L.D." objects to the London Branch decisions being made effective on the vote of 35 per cent. of members who attend general meetings, so do the rest of us object to his notion that the Association should be hung up by 6 per cent. or 7 per cent. of people who are "agin everything."

Yours faithfully,
"SEPTIMUS."

May 26, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—In the concluding paragraph of Mr. Walker's letter, he, the chairman of the National Executive of the A.E.S.D., complains that I abuse him. I have heard of Lucifer discoursing on the beauties of holiness, but that was not half so ludicrous as Mr. Walker complaining of being abused. No doubt he is an authority on abuse, but I decline to argue that point with him. I admit having penned some pointed and pertinent criticisms and am content to leave to your readers the task of deciding whether my remarks or the personalities he employed against your other correspondent are more deserving of the epithet "abuse." "O.L.D." has stated the case concisely in the last paragraph of his letter.

Mr. Walker's replies to my questions are more truthful than consistent. In his first letter he made a deliberate statement that "on vital matters a referendum is taken." Pinned down to three specific "vital matters" he is forced to admit that, to use his own words, "upon none of these matters did the Representative Council see fit to take a referendum." He then tries to mitigate the damaging effect of this admission by entering into long and irrelevant explanations as to why the referendum was not taken. Regarding the first point, affiliation to the Trades Union Congress, Mr. Walker informs us that this was regarded as being a "*natural corollary to being a trades union.*" I was one of the majority who voted in favour of becoming a trades union because we were told that it was for the protection of our funds, to obtain Government recognition, and that we ought to do so because the employers' federations were registered as trades unions. A member of the Law and Parliamentary Committee of the A.E.S.D. recently informed the Glasgow branch that affiliation to the Labour Party was the natural corollary to affiliation to the Trades Union Congress! This sheds rather a lurid light upon those "natural corollaries!" This brings me to my second point, affiliation to the Labour Party. Mr. Walker gravely informs us that "no ballot was taken on this proposal because it did not get through the conference. Had it done so a ballot would have been a legal necessity." What consistent inconsistency! Affiliation to the Trades Union Congress did pass the council, therefore a ballot is not necessary, but had affiliation to the Labour Party passed similarly a ballot would have been necessary! Affiliation to the Labour Party, like Kaiserism in Germany, is discredited because it did not succeed! It is just another case of "The devil was sick—the devil a monk would be; the devil was well—the devil a monk was he." As for my third point, that trifling matter of more than trebling the subscription, we are consoled by Mr. Walker's assertion that "the council took the view that it was necessary. Once more, no referendum was taken! He then goes on to state that some branches took a ballot. Yes, for instance, Glasgow, where of 1,533 voting members only 40 per cent. voted in favour of the increase, 26 per cent. voted against and 34 per cent. did not vote *or did not get the chance of voting*, yet by the operation of the "democratic" card vote the 1,533 Glasgow votes were all cast in favour of the increase at the conference. However to cut a long story short, Mr. Walker's statement that "on vital matters a referendum is taken" is admittedly untrue.

I am indebted to Mr. Walker for the information that the subsidy to the Labour Research Department was sanctioned by the Representative Council, but he evades my question as to whether the members were consulted by referendum or otherwise. He informs us that "the Labour Research Department is a unique storehouse of information." Thank goodness it is unique, but I suggest that "cook-house" would be a more accurately descriptive word to apply to it. It is a purely partisan organisation purveying propaganda for the Labour Party, subsidised over the heads and out of the pockets of Liberal and Unionist members of the A.E.S.D. Yet in face of all this Mr. Walker tells us "that on vital matters a referendum is taken." *Verbum sat sapienti.*

Yours faithfully,
"SCRUTATOR."

UNIVERSITY COLLEGE, LONDON.—The annual dinner of the Engineering Society will be held at the Holborn Restaurant on June 20, 1919. It is hoped to have a large gathering of old students, especially those who have served in His Majesty's Forces, to celebrate the Peace. Old students of the faculty are asked to communicate with Mr. J. A. Broughall, at Gower-street, if they wish to be present.

PHOSPHATES AND AMMONIA FROM SEWAGE.—The dearth of phosphate fertilisers throughout Germany has set chemists looking round again for new sources of phosphate. In the *Chemiker Zeitung* of January 21, 1919, J. Gonné, of Berlin, suggests to recover phosphates from the sewage. Without giving figures as to the probable yield to be expected he admits that the sewage treatment for phosphates alone would be unprofitable; but he claims to gain the ammonia at the same time and further to disinfect the sewage and to utilise the residue—familiar claims of workers on the sewage problem. He also points out that where ammonia is recovered from gas water his process might be worked in similar apparatus; but he is indefinite about his apparatus and process, likewise familiar features of sewage investigations. The chief point of his suggestion is that phosphoric acid is precipitated as calcium phosphate from solutions of calcium chloride and other calcium salts by sodium phosphate when ammonia is present. He separates the liquid from the solid sewage in special apparatus which prevent the escape of ammonia and also prevent explosion of any explosive gas mixtures. The clarification is facilitated by adding certain refuse or by-products of the process to the sewage. Calcium salts, also from the refuse, and some sodium phosphate, if necessary, are then added to the liquid, and the mud precipitated is filter-pressed or centrifuged. The settled liquid passes into distilling apparatus; more mud is obtained, and the precipitation and distillation are repeated.

THE MANUFACTURE AND WORKING OF HIGH SPEED STEEL.*

By J. H. ANDREW, D.Sc. (Chief of the Metallurgical Research Department, Sir W. G. Armstrong, Whitworth and Co., Limited, Openshaw), and G. W. GREEN (Assistant in the Metallurgical Research Department, Sir W. G. Armstrong, Whitworth and Co., Limited, Openshaw).

(*Concluded from page 670.*)

1¼-IN. SQUARE AND ROUND BILLETS.

After the last operation the bars are either rolled or tilted to 1¼ in. round or square. The data of these operations is shown in Tables V and VI.

MICROSTRUCTURE OF 1¼-IN. SQUARE AND ROUND BILLETS.

As to whether the work has been carried out through the rolls or upon the hammer appears to make little or no difference to the microstructure. The net effect of any reduction, however, performed being to elongate and eventually break up the carbide envelopes.

Micros 14 and 15, on page 717, show how completely these carbide laminations are broken up and elongated after a reduction to this size.

Having followed out in detail a series of observations particular to one forging it is unnecessary to dwell at any length upon some of the other operations involved where the mechanical work slightly differs, the tables at the end being self-explanatory and quite simple to follow. Moreover, it is always found that the microstructures of the forgings depend entirely upon the reduction and in no way differ in the rolled or forged bars, providing that the reduction is the same in both cases.

After reducing the diameter to 1¼ in. the bars are subjected to an annealing treatment, which consists of simply heating the bars up to a temperature of 900 deg. C., keeping that heat for sufficient time to soak, slowly cooling to 700 deg. C., and then allowing the bars to cool on the floor. After this treatment they are perfectly soft and machinable, they are then cut to length, and either machined or forged according to the type of tool to be made.

The old practice was to heat up to 800 deg. C. in 24 hours, then damp the furnace off from three to six hours, and finally the bars were allowed to cool down during the next 36 or more hours. It is thus seen that an annealing which required about three whole days to complete has now been replaced by one which requires at the most only 6 to 12 hours. The advantage, moreover, of this process of annealing is that it differs from the old one in so much as it refines the structure of the steel, a temperature of 900 deg. C. being above the critical point on heating; it is not therefore, as in other cases, merely a temper annealing.

We have advised this annealing—that is to say, heating slowly to 900 deg. C., then allowing to cool slowly to 700 deg. C.—to replace the previous method of annealing the cast ingots.

During the annealing of the ingot by the old method the cast structure was in no way refined. All that the annealing does is to bring about decomposition of the individual grains, leaving the high crystalline weakness still present in the ingot, whereas, if the ingot were taken above the critical point, breaking down of this cast structure would result, and apart from the persistence of the carbide envelopes, perfect refinement would be brought about. The forged bars are annealed similarly.

After an annealing of this character the bars are shaped first under the hammer, one heat being employed for the purpose, the bars being heated first slowly on the top of a smith's fire, and afterwards put in the hottest part and raised to a temperature of about 1050 deg. or 1100 deg. C. within three minutes. All heavy work is finished when the bar has cooled to 800 deg. C., after which it is inserted in the smith's fire and receives the second and third light shapings on the anvil. This shaping applies only to lathe tools, such tools as milling cutters, twist drills, &c., being machined directly after annealing.

Tables VII and VIII refer to rolling and tilting from 2½ in. square down to 1¼ in. round and square; reference to the first table will show how these come into the working scheme.

HARDENING.

Lathe tools are hardened by the usual method of gradually bringing the tool up to a medium red heat and then putting it into the hottest part of a muffle furnace and allowing the nose to attain a temperature between 1,290 deg. and 1,300 deg. C.; after this the tool is quickly withdrawn from the furnace and cooled off in the air blast or in oil, as the case may be.

In the actual hardening temperatures determined, the variations from the ideal were but slight in the tools followed through; the minimum temperature was 1,290 deg. C. and the maximum temperature 1,330 deg. C., whereas in the case of hardening large drills a minimum of 1,240 deg. C. and a maximum of 1,290 deg. C. were observed.

The time taken in heating up for hardening was also found to vary but little in each case, the shortest possible time consistent with adequate soaking being employed.

The factors of time and temperature both work in the same direction. High temperature, by promoting greater molecular mobility, will promote excessive grain growth, whilst prolonging the time of heating acts in the same direction. Although high temperature may promote greater solution of the free carbide this means should not be used for that purpose, as the result would be large grain growth, whereas even at the high temperature of hardening it was found that massive carbide, if it existed in the tool previous to this operation, was only with difficulty even partially got into solution.

As an illustration of the enormous effect of slight differences in hardening high-speed steels, five micros (Nos. 16 to 20) are shown on pages 717 and 718.

No. 16 shows an improperly hardened steel, the temperature not having been high enough.

No. 17 is a steel in the ideal hardened condition; this was hardened at 1,300 deg. C.

No. 18 is a steel overheated in hardening. Note the increase in the size of grain. This was hardened at 1,305 deg. C.

No. 19 is of a steel hardened at 1,310 deg. C. and shows the almost complete absence of free carbide, and how its liquefaction has caused it to resolidify on the grain boundaries with a characteristic eutectic structure.

No. 20 shows a steel hardened at about 1,320 deg. C. which has become slightly "crozzled."

* Paper read before the Iron and Steel Institute, on Friday, May 9, 1919.

TABLE V.—ROLLING FROM 1¼-IN. SQUARE TO 1¼-IN. ROUND.

No.	Total Time.	Rolling. No. of Passes.	Rolling. Average Time per Pass.	Rolling. First Pass Temp.	Rolling. Last Pass Temp.	Rolling. Average Temp. Drop per Pass.	Type of Billet.	Fracture.	Microstructure.	Brinell.
	secs.		secs.	deg. C.	deg. C.	deg. C.				
A1Y	120	15	8	1,030	870	10·6	Good	Very fine crystalline. No trace of overheating. As hardened tool steel.	Austenite decomposing irregularly. Carbide lines which are smaller than the average.	
A2Y	105	18	6	1,030	830	11·0	,,	,, ,,	Austenite decomposing. Carbide lines and segregations.	
A3Y	90	17	5·3	1,030	860	10·0	,,	,, ,,	,, ,,	

TABLE VI.—TILTING FROM 1¼-IN. SQUARE TO 1¼-IN SQUARE.

No.	First End. Forging. Time.	First End. Forging. First Temp.	First End. Forging. Last Temp.	Time to Heat from Cold.	Second End. Forging. Time.	Second End. Forging. First Temp.	Second End. Forging. Last Temp.	Type of Billet.	Fracture.	Microstructure.	Brinell.
	min.	deg. C.	deg. C.	min.	min.	deg. C.	deg. C.				
A1T	1½	1,100	900	11	2	1,110	790	Good	Fine crystalline. Trace of overheating. Similar to hardened tool steel.	Austenite decomposing very irregularly. Carbide "lines" and some segregation. From outside to centre the metal becomes less homogeneous.	
A2B	2½	1,110	790	15½	3½	1,140	810	,,	,, ,,	Austenite decomposing. Fine carbide lines and small segregations.	
A3B	2	1,100	870	13	2½	1,110	850	,,	,, ,,	,, ,,	
A4T	1½	1,060	875	15	1½	1,050	850	,,	,, ,,	,, ,,	

TABLE VII.—ROLLING FROM 2½ INCHES SQUARE DOWN TO 1¼ INCH ROUND.

No.	Temp. Coming out of Furnace.	Rolling. Total Time.	Rolling. No. of Passes.	Rolling. Average Time per Pass.	Rolling. First Pass. Temp.	Rolling. Last Pass Temp.	Rolling. Average Temp. Drop per Pass.	Type of Billet.	Fracture.	Microstructure.	Brinell.
	deg. C.	sec.		sec.	deg. C.	deg. C.	deg. C.				
A1B	1050,	136	18	7·5	Missed 5th Pass 1,015	830	13·0	Good	Similar to hardened tool steel fracture.	Austenite decomposing. Carbide "lines."	
A2T	1,030	79	18	4·5	Missed 2nd Pass 1,040	Missed 16th Pass 945	6·6	,,	,, ,,	,, ,,	
A3T	990 Scale Chilled	110	18	6·0	Missed 2nd Pass 1,090	Missed 17th Pass 880	13·0	,,	"(Flaw)"	,, ,, Decomposition of austenite is very irregular.	
A4B	990 Scale Chilled	101	18	5·5	Missed 2nd Pass 1,100	895	12·0	,,	,, ,,	Austenite slightly decomposed.	

TABLE VIII.—TILTING FROM 2½ INCHES SQUARE TO 1¼ INCH SQUARE.

No.	Forging 1st End. Time to Heat.	Forging 1st End. Forging Time.	Forging 1st End. First Temp.	Forging 1st End. Last Temp.	Forging 2nd End. Time to Heat.	Forging 2nd End. Forging Time.	Forging 2nd End. First Temp.	Forging 2nd End. Last Temp.	Type of Billet.	Fracture.	Microstructure.	Brinell.
	min.	min.	deg. C.	dge. C.	min.	min.	deg. C.	deg. C.				
A1Bx	19½	5½	1,100	750	27½	3	1,080	750	Good	Similar to hardened tool steel.	Ground-mass of decomposing austenite. Carbide lines very fine and drawn out. Close to the surface the lines are broken up.	
A2Tx	23	3½	1,070	760	22	2½	1,080	830	,,	,, ,,	Ground-mass of decomposing austenite. Carbide lines and several segregations.	
A3Tx	17	3½	1,060	720	17	2	1,080	890	,,	,, ,, (Doubtful signs of overheating)	Austenite decomposing irregularly; some areas hardly decomposed. Carbide lines which are fairly well decomposed near the surface only.	

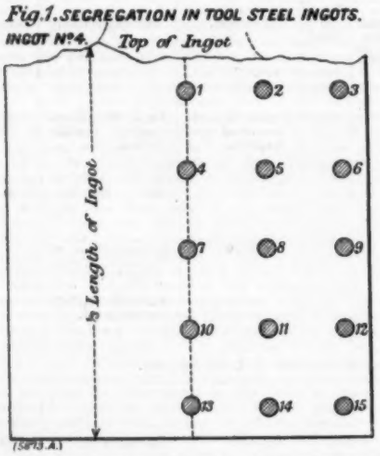
TABLE IX.—FORGING AND HARDENING OF TOOLS.

All tools specially for cutting tests.

No.	No. of Tool.	Forging. Cutting Bars to Length. Time to Heat.	Temp	Forging under Hammer. Time to Heat.	Temp.	Time under Hammer.	First Shaping on Anvil. Time to Heat.	First Temp.	Last Temp.	Time.	Second Shaping on Anvil. Time to Heat.	First Temp.	Last Temp.	Time.	Hardening. Time to Heat.	Temp.	Time to Black.	Microstructure.	Brinell.
		min.	deg. C.	min.	deg. C.	min.	min.	deg. C.	deg. C.	min.	min.	deg. C.	deg. C.	min.	min. sec.	deg. C.	min. sec.		
A1T	1	4	1,000	3	1,040	1	1	1,050	850	1½	¾	1,070	680	1¾	2 45	1,290	2 0	Pure austenitic grains and small amount of free carbide.	
A1Y	—	—	—	3½	1,050	1	1	1,070	750	1¾†	¾	1,080	680	1¾	2 20	1,300	1 30	Austenitic grains of large size. No free carbide. The grain boundaries contain the carbide eutectic showing that incipient fusion has taken place. Overheated.	
	Blank*	—	—	—	—	—	—	—	—	—	—	—	—	—	3 15	1,310	—		
A1B	—	—	—	4	1,025	1	¾	1,070	840	1½	¾	1,085	720	1½	2 30	1,300	1 30	Pure austenitic grains of medium size and small amount of free carbide as lines and globules.	
	Blank	—	—	—	—	—	—	—	—	—	—	—	—	—	2 40	1,305	—		
A1Bx	8	2½	1,050	4	1,075	1	1	1,080	820	1¾	¾	1,070	680	2	2 30	1,300	1 45		
A2B	1	4	990	3	1,040	1	1	1,070	820	1¾	¾	1,070	680	1¾	2 52	1,290	2 0		
A2Y	—	—	—	4	1,050	1	1	1,080	800	1½	¾	1,050	680	1¾	2 15	1,300	1 45	Pure austenitic grains of large size. Free carbide as lines and globules. Overheated.	
	Blank	—	—	—	—	—	—	—	—	—	—	—	—	—	3 0	1,305	—		
A2T	—	—	—	3	1,020	1	¾	1,090	855	1	¾	1,060	700	1½	2 15	1,305	1 20	Pure austenitic grains, fairly large. Free carbide as dots, &c.	
	Blank	—	—	—	—	—	—	—	—	—	—	—	—	—	2 30	1,300	—		
A2Tx	8	3	1,040	—	1,050	1	¾	1,100	890	1	¾	1,090	680	1¾	2 20	1,300	1 30		
A3B	1	5	1,040	3	1,050	1	1	1,060	800	1¾	¾	1,060	680	1¾	2 53	1,290	1 50	Pure austenitic grains, fairly large. Free carbide as lines and globules. Somewhat overheated because of time at heat.	
	Blank	—	—	—	—	—	—	—	—	—	—	—	—	—	2 53	1,300	—		
A3Y	—	—	—	—	1,050	1	¾	1,080	870	1½	¾	—	680	1¾	2 30	1,300	1 30	Pure austenitic grains, fairly large. Free carbide as lines and globules. Overheated.	
	Blank	—	—	—	—	—	—	—	—	—	—	1,030	—	—	2 40	1,305	—		
A3T	—	—	—	3	1,020	1	—	1,090	855	1	¾	1,060	700	1½	2 30	1,305	1 20	Pure austenitic grains, medium size. Free carbide as dots and lines.	
	Blank	—	—	—	—	—	¾	—	—	—	—	—	—	—	2 40	1,300	—		
				delay															
A3Tx	1	—	—	10	1,000	1	¾	1,110	900	1	¾	1,110	710	1½	2 30	1,300	1 30		
A4T	1	—	—	10	1,000	1	¾	1,100	900	1	¾	1,100	700	1½	2 30	1,300	1 30		
A4B	—	—	—	2½	1,040	1	1	1,110	880	1½	¾	1,080	700	1½	2 15	1,300	1 30		
	Blank	—	—	—	—	—	—	—	—	—	—	—	—	—	2 30	1,300	—	Pure austenitic grains of varying size. Free carbide as dots and lines.	

* The term "Blank" refers to pieces used for micro. purposes. † Small crack ground out.

Fig. 1. SEGREGATION IN TOOL STEEL INGOTS.



	C.	Mn.	P.	S.	Si.	W.	Cr.	V.
1	0·60	0·08	0·008	0·060	0·210	13·94	3·77	0·51
2	0·60	0·08	0·010	0·059	0·210	13·98	3·73	0·52
3	0·63	0·08	0·010	0·057	0·200	14·21	3·84	0·51
4	0·55	0·08	0·014	0·060	0·198	14·19	3·84	0·52
5	0·60	0·08	0·015	0·060	0·210	14·16	3·85	0·52
6	0·63	0·08	0·012	0·059	0·198	13·98	3·84	0·52
7	0·61	0·09	0·015	0·058	0·196	14·21	3·89	0·52
8	0·60	0·08	0·010	0·057	0·198	14·08	3·87	0·52
9	0·61	0·08	0·014	0·057	0·198	14·14	3·81	0·52
10	0·60	0·08	0·014	0·057	0·186	14·04	3·89	0·52
11	0·57	0·08	0·012	0·056	0·186	14·16	3·87	0·52
12	0·61	0·08	0·014	0·056	0·186	14·20	3·89	0·52
13	0·60	0·08	0·012	0·059	0·186	13·89	3·88	0·52
14	0·58	0·08	0·004	0·059	0·186	14·00	3·91	0·52
15	0·58	0·08	0·010	0·057	0·177	14·21	3·91	0·52

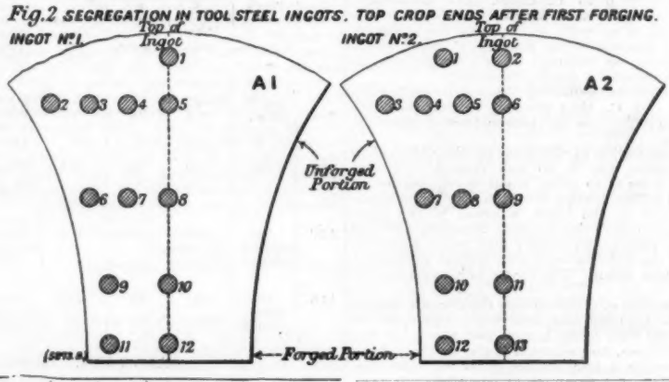
No. 21 shows a specimen completely "crozzled" at 1,330 deg. C.

All temperatures are actual observations without corrections. It is seen from this that at observed temperatures about 1,305 deg. C. liquefaction of the carbide begins.

This agrees well with Yatsevitch's work, as published in *Revue de Metallurgie*, 1918, in which he shows from a heating curve that the solidus of a steel of similar composition occurs between 1,330 deg. and 1,335 deg. C., the melting-point in heating being 1,450 deg. C. Upon cooling from the melt, the same author shows that whereas freezing commences at 1,450 deg. C., the metal is not completely solidified until a temperature of 1,280 deg. to 1,285 deg. C. is obtained.

The effect of this is that this liquid solidifies on cooling again around the boundaries of the crystals as a eutectic.

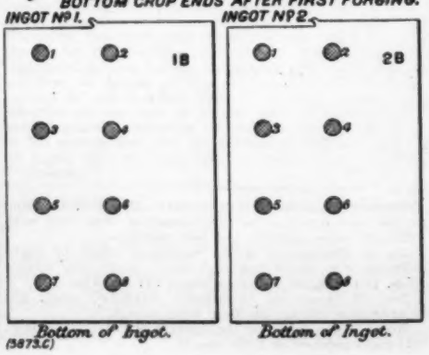
Fig. 2 SEGREGATION IN TOOL STEEL INGOTS. TOP CROP ENDS AFTER FIRST FORGING.



No.	C.	Mn.	P.	S.	Si.	W.	Cr.	V.
1	0·43	0·08	0·01	0·036	0·177	13·86	3·69	0·48
2	0·60	0·08	0·01	0·037	0·177	14·16	3·88	0·52
3	0·63	0·08	0·01	0·039	0·128	14·17	3·87	0·52
4	0·58	0·08	0·01	0·037	0·140	14·21	3·85	0·52
5	0·53	0·09	0·01	0·041	0·140	14·21	3·82	0·52
6	0·62	0·08	0·011	0·041	0·140	14·25	3·88	0·52
7	0·57	0·08	0·012	0·044	0·140	14·25	3·87	0·52
8	0·61	0·08	0·013	0·044	0·140	14·16	3·85	0·51
9	0·63	0·08	0·01	0·038	0·140	14·25	3·85	0·51
10	0·55	0·08	0·01	0·038	0·128	14·08	3·85	0·50
11	0·62	0·08	0·015	0·043	0·152	14·21	3·88	0·50
12	0·61	0·08	0·011	0·039	0·152	14·08	3·83	0·50

	C.	Mn.	P.	S.	Si.	W.	Cr.	V.
1	0·57	0·08	0·01	0·035	0·152	14·08	3·84	0·47
2	0·57	0·08	0·011	0·036	0·152	13·90	3·82	0·47
3	0·58	0·09	0·011	0·036	0·152	14·17	3·92	0·48
4	0·55	0·09	0·011	0·039	0·140	14·13	3·90	0·48
5	0·60	0·08	0·01	0·042	0·152	14·23	3·90	0·48
6	0·60	0·09	0·01	0·042	0·140	14·77	3·88	0·49
7	0·58	0·08	0·01	0·037	0·140	14·25	3·88	0·46
8	0·59	0·08	0·01	0·039	0·140	14·25	3·90	0·46
9	0·61	0·08	0·01	0·039	0·140	14·21	3·88	0·46
10	0·59	0·08	0·01	0·042	0·140	14·29	3·84	0·46
11	0·58	0·08	0·01	0·042	0·140	14·21	3·87	0·46
12	0·59	0·08	0·01	0·041	0·140	14·29	3·84	0·47
13	0·56	0·08	0·01	0·036	0·128	14·19	3·82	0·45

Fig. 3. SEGREGATION IN TOOL STEEL INGOTS. BOTTOM CROP ENDS AFTER FIRST FORGING.



Ingot No. I (Fig. 3).

	C.	Mn.	P.	S.	Si.	W.	Cr.	V.
1	0·59	0·09	0·015	0·044	0·186	14·16	3·88	0·51
2	0·60	0·09	0·015	0·041	0·177	14·22	3·88	0·51
3	0·61	0·08	0·012	0·042	0·186	14·12	3·90	0·51
4	0·59	0·08	0·012	0·041	0·186	14·16	3·88	0·51
5	0·59	0·09	0·014	0·044	0·198	14·19	3·90	0·51
6	0·60	0·09	0·015	0·041	0·198	14·12	3·88	0·50
7	0·60	0·09	0·016	0·042	0·198	14·12	3·88	0·50
8	0·61	0·09	0·015	0·043	0·198	14·16	3·90	0·51

Ingot No. II (Fig. 3).

	C.	Mn.	P.	S.	Si.	W.	Cr.	V.
1	0·54	0·09	0·015	0·043	0·152	14·46	3·87	0·49
2	0·59	0·09	0·011	0·043	0·163	14·08	3·88	0·50
3	0·56	0·09	0·014	0·043	0·163	14·21	3·88	0·49
4	0·57	0·09	0·008	0·044	0·152	14·12	3·88	0·49
5	0·58	0·10	0·009	0·042	0·163	14·12	3·88	0·50
6	0·59	0·09	0·010	0·042	0·163	14·13	3·88	0·48
7	0·58	0·10	0·008	0·044	0·163	14·27	3·88	0·48
8	0·58	0·09	0·015	0·044	0·163	14·08	3·88	0·48

These differences, occurring as they do with slight variation in temperature, are very striking.

The hardening data for a number of tools followed is given on Table IX, on the opposite page.

Cutting Tests.

A few cutting tests of the steels after being properly hardened were taken. The results of these are given below :—

Tool No.	Horse-Power. Light	Horse-Power. Full Load.	Feed.	Depth of Cut.	Speed per Minute.	Time to Break Down.
			in.	in.	ft.	minutes.
1	15	40	1/8	1/8	80	22
2	15	40	1/8	1/8	80	21¼
3	15	40	1/8	1/8	82	15

The billet used for the cutting tests was not annealed ; it was of the following composition :—

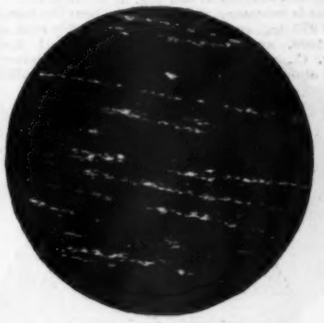
	Per Cent.
Carbon	0·32
Manganese	0·5
Silicon	0·114
Sulphur	0·028
Phosphorus	0·041
Nickel	0·22

The test from this material broke at 33·8 tons per square inch.

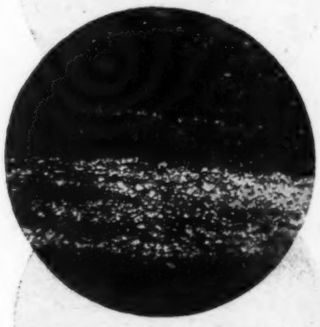
Fig. 1 is from the top third of ingot No. 4.
Fig. 2 is from the crop ends of ingots 1 and 2.
Fig. 3 is from the bottom crop ends of ingots 1 and 2.

It will be seen that no segregation—even of carbon, sulphur, or phosphorus—has occurred, and that the tiny carbide segregations which were frequently observed in the micro examinations are not units of large ingot segregations.

The absence of segregation is probably due to two causes : (1) Small size of ingot ; (2) very quick solidification due to the chilling effect of the moulds and to the presence of large quantities of special elements in the steel.

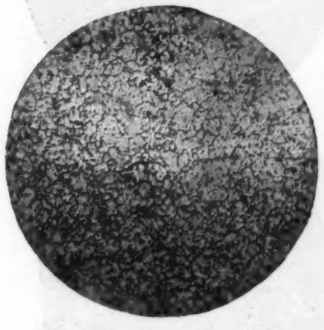


No. 14.—Final arrangement of carbide envelopes. × 200.

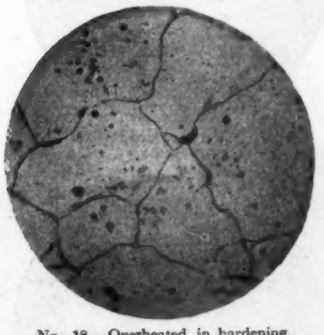


No. 15.—Final arrangement of carbide segregation. × 200.

No. 16.—Improperly hardened steel. Temperature not high enough. × 200.



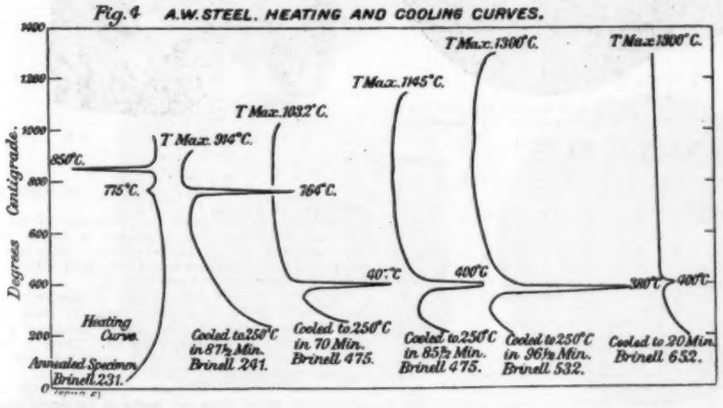
No. 17.—Ideal hardened condition. Temperature 1500°C. × 200.



No. 18.—Overheated in hardening. Temperature 1305°C. × 200.

All reduced by one-third.

Fig. 4 A.W. STEEL. HEATING AND COOLING CURVES.



Segregation of Tool Steel Ingots.

Series of analyses were taken from the top third of one ingot and from the top and bottom crop ends of two others of those whose manufacture and further treatment had been followed through. The results are tabulated in Figs. 1, 2 and 3, on the opposite page.

The before-mentioned two causes are in the main the reasons for the almost entire absence of blowholes in these ingots.

Experiments upon the Elimination of Carbide Lines.

The chief source of trouble in certain classes of tools, especially large milling cutters, hobs, &c., which cannot receive as much work as, say, a lathe tool or twist drill, is invariably found to be due to the presence of laminated carbide lines. These carbide lines, which are forged out and elongated segregates formed from the melt, are most difficult to eliminate when once formed. The carbide in question is the massive carbide at the boundaries.

If once the carbide be taken into solution and afterwards deposited from the same, it comes out of solution in the form of small dots or nodules, and in this finely divided state is readily taken into solution during the hardening process. Such carbide therefore that comes out upon annealing is in no way detrimental.

An ordinary hardening treatment, owing to the necessity of its being carried out as quickly as possible, is totally insufficient to enable the massive carbide segregates to be disposed of.

A number of experiments were therefore tried in order to determine the effect of a prolonged soaking of a segregated piece of metal at a temperature between 1,150 deg. and 1,200 deg. C. A piece of tool steel was packed in a non-oxidising material in a crucible and heated between these temperatures for a period of 6 hours ; it was then slowly cooled in the furnace, taken out, broken, and half of the piece again put back for another 6 hours, the same process being gone through whilst another piece was given a further 6 hours. Thus the effects of high temperature annealings carried out for 6 hours, 12 hours and 18 hours respectively were determined.

The microstructure after these successive treatments presented each time similar carbide boundaries which existed in the original cast structure. After this treatment they were thinner and less massive, but were very sharply defined.

Micros 22 *and* 23 (page 718).—The comparison of these with micros 2 and 3, page 672 *ante*, indicate that whilst a certain amount of solution has occurred, this is insufficient to recommend this process. One of the pieces tried became highly oxidised, the fracture of the oxidised bar showing the peculiar structure depicted in No. 24.

This fracture consisted of very large bright crystals with one axis longer than the other, the longer axis being normal to the surface, whereas the central core consisted of fine equiaxial crystals.

Upon polishing this section it was noticed that the core stood out in relief above the rest of the metal, an indication of the hardness at the centre. Etched with nitric acid a peculiar macrostructure resulted which is shown in No. 25.

This macro shows all the characteristics of the fracture. The outside ring consisted of very large grains, the boundaries of which were often skirted with well-developed pearlite, the grains themselves consisting of a homogeneous light etching material, ferrite, in which are embedded a number of massive carbide segregates.

The large grains end abruptly at the pearlite boundary which totally encloses the central core, the latter part consisting of pure austenite and massive carbide.

The interesting points with regard to this decarburisation are, firstly, that the decarburisation gradient is very steep at the pearlite boundaries ; that this pearlite boundary, which is very thin, is a distinct line of demarcation between the almost carbonless and completely softened steel and the austenite. The massive carbide resists decarburisation better than any other of the structural elements. It is obvious that ordinary tool steel is of a decidedly hypereutectoid nature.

Brinell Hardness of A.W. Steel.

The Brinell hardness was measured after each operation in the manufacture of the tools, and the results condensed in the following table :—

Operation.	Brinell. Average.	Brinell. Highest.	Brinell. Lowest.	Number of Determinations.
After annealing ingot	259	262	255	16
After cogging to 3½ in. square	540	600	505	19
After rolling from 3½ in. to 2½ in.	604	652	555	9
After cogging from 3½ in. to 1½ in.	610	562	600	15
After tilting to 1¼ in. square	616	652	600	18
After rolling to 1¼ in. round				
After annealing ..	249	269	231	12
After hardening ..	652	—	—	—

It will be noted that with decrease in cross-section there is a corresponding increase in the Brinell hardness number.

Heating and Cooling Curves of A.W. Steel.

On Fig. 4 will be found a heating curve followed by a series of cooling curves of A.W. steel taken from different temperatures and with varying rates of cooling.

Heating Curves.—Two points are shown, a small one with a maximum of 775 deg. C., and a larger one (maximum 850 deg. C.). The exact significance of the lower point has not yet been determined.

A steel when heated and quenched above the lower point reveals no alteration in hardness, the value obtained being 231, which is that of the annealed steel. The microstructure is represented by micro No. 27. This micro differs from that of the annealed steel, micro 26,

in that the ground-mass contains a considerably greater proportion of smaller white dots.

The upper point, maximum 850 deg. C., appears to be similar to the ordinary Ac3,2,1 change, the temperature of this change being raised very considerably by the combined presence of tungsten and chromium.

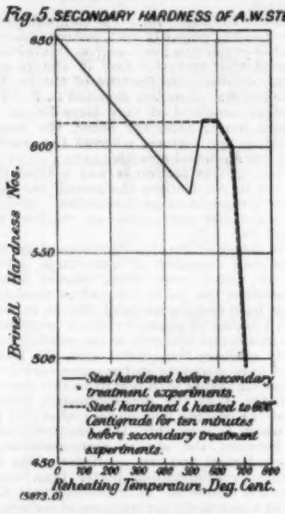
A steel quenched above the upper point on heating, namely, 880 deg. C., has a hardness of 532, and a microstructure similar to No. 28. This structure, although similar in appearance to that of the annealed steel, is totally different. The white blobs of separated carbide, one must assume, are the same in both cases. The matrix in this case, however, is martensitic.

Cooling Curves.—Cooling from an initial temperature of 914 deg. C. one large evolution of heat is shown at 764 deg. C. The change from the hard to the soft state is so complete in cooling from this temperature even at a moderately rapid rate that the hardness has been reduced to 241.

Cooling from an initial temperature of 1,032 deg. C. the critical point is depressed to 407 deg. C.; this depression progresses slightly with the maximum initial temperature until at a temperature of 1,300 deg. C., with very slow cooling, a very large evolution of heat is obtained at 380 deg. C. The variation in hardness with increasing temperature is rather remarkable. With an initial temperature of 1,032 deg. C. and also of 1,145 deg. C. with furnace-cooled specimens the Brinell figure was 475. With an initial temperature of 1,300 deg. C. slowly cooled (96 minutes) the hardness figure jumped to 532.

If we compare the steels cooled from 1,145 deg. and 1,300 deg. C. respectively, we note that although the latter presents a larger evolution of heat at the critical point, the resulting product is harder. This can only be accounted for by assuming that a definite chemical or physical change takes place in the metal at the high temperature, with the result that the product deposited as the steel passes through the recalescence point, or the remaining solution, is harder than in the case of the

Fig. 5. SECONDARY HARDNESS OF A.W. STEEL.



steel cooled from 1,300 deg. C.; that is to say, there must be some radical change in constitution between the temperature of 1,145 deg. and 1,300 deg. C. This agrees with Yatsevitch, who found that the higher the initial temperature, the larger the evolution at the critical point and the greater the hardness.

With a moderately rapid cooling from 1,300 deg. C. a small point is observed at 400 deg. C., whereas if air-blast is employed a curve free from all critical points is obtained. This represents the rate of cooling that should be attempted in practice. A steel quenched from 1,300 deg. C. has a structure shown in micro 29, which is similar to that of a steel quenched in the air-blast.

ANNEALING TREATMENT.

As before mentioned, the system adopted in the works for the annealing of tools occupied about three days' time. It was obvious, however, after taking a cooling curve from 914 deg. C. and measuring the resulting hardness of the specimen, which was 241, that a far quicker and simpler treatment might be employed to produce the same effect. Accordingly specimens about 1 in. square of A.W. steel were taken, and in order to get them in a state similar to that of the ingot or forging, they were air-hardened to 1,300 deg. C. It is true that this treatment would rather exaggerate the nature of the case, but the exaggeration is on the right side, so that any treatment which would bring about softening of these specimens would have a similar effect on those in practice.

The table alongside summarises the experiments.

The aim of these experiments was to take the steel to a temperature slightly above the critical point on heating, and to avoid taking it to a temperature which would produce any self-hardening, which occurs when the maximum temperature is such that a recalescence at about 400 deg. C. begins to show.

It is seen from the table that a temperature of 950 deg. C. is the maximum limit to which the steel can be heated in order to bring about complete softening. The maximum that should be employed in practice to give the best results is 935 deg. C., whilst the minimum to effect the same is 870 deg. C.

Experiments carried out at a temperature of 800 deg. C., which is similar to that employed in practice, show that even after 4 hours' soaking at this temperature, the softening was not so pronounced as that produced by half an hour's soaking at 935 deg. or 870 deg. C.

All that is necessary, therefore, is to heat the bars up to between 870 deg. and 935 deg. C., thoroughly soak at this temperature, and cool off within about 1 hour to 740 deg. C., when complete softening will have been brought about. After this the bars may be pulled out and cooled quickly in air.

SECONDARY HARDENING.

Some experiments of the type carried out by Professor Edwards upon secondary hardening treatment gave the results shown in Fig. 5. The full line indicates hardness after various tempering temperatures, the initial hardening being carried out at 1,300 deg. C. The usual minimum is seen at a temperature of about 500 deg. C., rising to a maximum between 550 deg. and 600 deg. C. The dotted line shows the effect of tempering at various temperatures after hardening and a preliminary secondary hardening carried out at 600 deg. C.

It is thus seen that the effect of secondary hardening, although it lowers the initial hardness of the specimen, does increase the stability of the steel. After this treatment the hardness remains constant throughout up to a temperature just above 600 deg. C.

Max. Temp.	Time at Heat.	Time Cooling to 740 deg. C.	Brinell Number.
deg. C.	hours.		
945	½	1½ hours	302
940	nil	½ hour	475
935	½	1½ hours	269
900	½	1½ hours. Water quenched ..	255
		1½ hours. Air cooled	253
		1½ hours. Furnace cooled ..	243
		1½ hours. Very slowly cooled ..	248
870	½	1 hour	269
860	nil	20 minutes	302
800	½	Water quenched from 800 deg. C.	340
	1	Furnace cooled	321
	1½	Furnace cooled	302
	2	Furnace cooled	293
	3	Furnace cooled	287

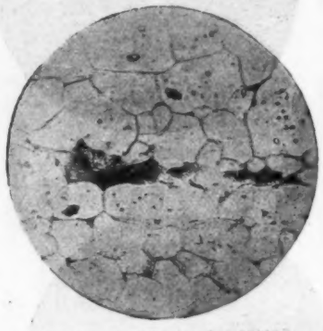
FAILURES IN TOOLS.

Failures arise in tool steel due to various causes. Some may be traced back to faulty casting, others to faulty rolling, and also to faulty hardening. As regards carbon steels, faults in general have been thoroughly treated by H. Brearley in his numerous text-books, not so fully, however, with regard to high-speed steels.

Failures Due to Casting Conditions.—If too high a casting temperature is employed a highly dendritic structure will result. This structure, which is naturally weak, cannot be afterwards obliterated either by heat treatment or even mechanical work.

Micro 30 shows a typical case of dendritic structure occasionally found in a faulty tool. In these it is seen that the dendrites are very clearly developed and form beautiful fir-tree crystal skeletons. There is no need to dwell upon the statement that this structure is mechanically weak.

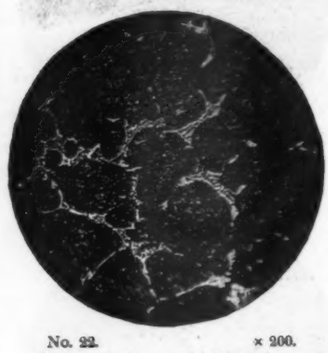
Failures Due to Segregation.—Although the analyses previously given from all parts of an ingot show that practically no segregation occurs in tool steel, the authors have come across one case where this did occur. Micro 31, taken at 5 diameters, shows a large segregation right in the centre of the nose of a twist drill. This segregation, which was harder and more brittle than the surrounding metal, naturally was the cause of failure of the tool.



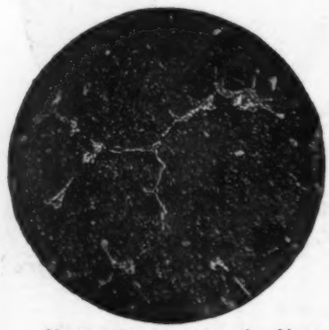
No. 19.—Steel hardened at 1310°C. × 200.

No. 20.—Steel hardened at 1320°C. × 200.

No. 21.—Steel hardened at 1330°C. × 200.



No. 22. × 200.



No 23.—Effect of prolonged soaking at 1150° to 1200°C. of segregated piece of tool-steel. × 200.

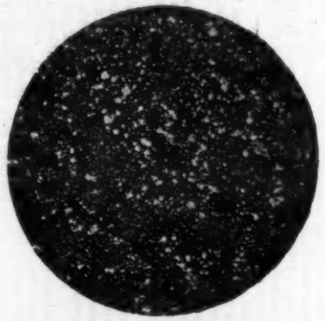
No. 24.—Fracture of bar. × 8.

All reduced by one-third.

THE MANUFACTURE AND WORKING OF HIGH SPEED STEEL.

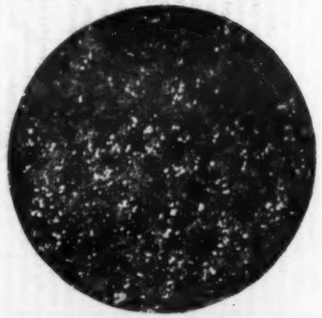
(*For Description, see Page* 715.)

No. 25.—Macrostructure after etching with nitric acid. × 8.



No. 26.—Annealed. × 200.

No. 27.—Water quenched from just above the lower point. × 200.



No. 28.—Water quenched from just above the higher point. × 200.

No. 29.—Water quenched from 1300°C. × 200.

No. 30.—Dendritic structure found in faulty tool. × 4.

All reduced by one-third.

No. 31.—Showing segregation in centre of nose of twist drill. × 2.

No. 33.—Showing forging crack. × 20.

No. 32 – Showing small roak developed by forging. × 20.

No. 34.—Showing typical laminated carbide lines not obliterated by forging. × 100.

No. 35.—Typical case of crack in steel hardened at an insufficiently high temperature. × 100.

No. 36.—Longitudinal section of 0·35 carbon steel shaving. × 100.

Figs. 31 and 33 reduced by one-half; Figs. 32, 34, 35 and 36 reduced by one-third.

Failures Due to Slag.—The occurrence of slag and manganese sulphide is very rare in tool steel; occasionally however, they are met with.

Casting Phenomena which are Actuated by Mechanical Treatment.—Micro 32 shows a small roak developed by forging. The crack which was therefore originally in the ingot has been distorted and extended by forging.

Micro 33 shows rather a different case of crack, this being more in the nature of what is generally termed a forging crack. Here it is seen that the crack is filled, not purely with oxide material, but also with slaggy material picked up in the furnace during heating up for forging, the forging process squashing this in, as it were, and slightly extending the crack.

Carbide Segregations.—These are undoubtedly the most troublesome features that arise in tool steel. They usually only occur in the case of tools of such large size as to permit little forging to be put into them. Micro 34 shows typical laminated carbide lines, which have not been obliterated and pulled to pieces by the forging treatment. They are of the noted hook or crook shape so detrimental to tool steel. It should also be noted in passing that this tool had been hardened at an excessively low temperature, shown by the composite structure of the matrix. Sometimes these carbide segregations exist as envelopes around the grains. This indicates even less drastic forging than the former case.

Carbide out of solution in steel in any form other than small specks is invariably found to be detrimental.

Micro 35 shows a rather curious case of a crack running through the steel in no particular direction—that is to say, its course is not determined by the grain boundaries or carbide envelopes. Cracks of this nature are occasionally found in a steel, of which this is a typical example, which has not been hardened at a sufficiently high temperature, the metastability of a semi-hardened structure being far greater than that of a properly hardened structure, the nuclei of the stable phase creating a tendency for a volume change to take place n the metal which will cause a crack.

Micro 36 is merely added for interest. It represents he longitudinal section of a shaving of a 0·35 per cent. carbon steel about $\frac{1}{8}$ in. thick, which was taken off during the cutting tests.

The distortions formed by the ferrite are clearly visible in the photograph, which shows the usual effect of strain of this character.

Summary and Conclusions.

The whole process of manufacture of high-speed steel has been followed through, and it must be admitted that greater uniformity of working is hardly possible.

As far as casting is concerned, some slight improvement might be made by increasing the thickness of the mould walls and lowering the pouring temperature of the metal.

An investigation of the various forging operations of cogging, rolling, &c., has been made, and it has been found that, for efficient forging, temperatures must be used which are appreciably higher than those generally accepted as correct.

It is also shown that whether reduction is effected by rolling or hammering, or a combination of both, there appears to be little or no difference in the microstructures.

What is, however, of the utmost importance is the amount of reduction in forging which the metal undergoes between the cast state and the finished bar.

Micros taken after various processes of forging and rolling indicate that below a reduction of 88 per cent. for a 6-inch ingot, the distorted carbide envelopes occur in the form of loops and hooks of various configurations, and it is in this form that they are most dangerous. This is a point emphasised by Brearley in his book on tool steel.

Finished milling cutters which have broken in use owing to carbide laminations invariably show the laminations to be in this form. If the laminations are discontinuous and broken up they seldom give rise to trouble. From this we must conclude that the reduction should even go beyond this figure. For large tools, therefore, it is desirable to cast a larger ingot and to put more work into the steel.

Experiments have shown that carbide in the finely separated state can be readily made to go into solution at a sufficiently high temperature. If, however, it occurs in the massive form as in the carbide envelopes or laminations, it is almost impossible to bring this about, as has been shown by the experiments mentioned, namely, by high temperatures soaking.

With regard to annealing treatment, all that is necessary to bring about complete softening of the steel is to heat the steel just above its higher critical point on heating, and slowly cool down through the point on cooling.

Hardening times and temperatures are of the utmost importance. Grain growth in high-speed tool steel is certainly slow when compared with carbon steel at low temperatures, but at the high hardening temperatures it is rapid enough to give rise to a very coarse structure even with an increase of 20 per cent. in a hardening time of 2½ minutes.

The temperature limits for really efficient hardening are as narrow as 10 deg. C. Hardening should be carried out between the temperatures of 1,300 deg. and 1,320 deg. C. (corrected temperatures). If the temperature is above 1,320 deg. C. overheating and finally burning will occur, whereas, if below 1,300 deg. C., an insufficiently hardened steel will result. In either case defective tools will result.

The cooling curve data agrees very well with similar determinations made by Yatsevitch.* On the basis of his freezing curves the burning of the tool steel when heated above 1,330 deg. C. is readily explained.

The various defects occurring in high-speed steel have been reviewed and commented on. The greatest troubles are due to the insufficiently distorted carbide envelope and correct hardening.

The authors wish to express their thanks to Messrs. Sir W. G. Armstrong, Whitworth and Co. Limited, and especially to Mr. F. B. Trevelyan, for their kind permission to publish these results, also to Mr. E. F. Law for the interest he has taken in the work. They are likewise indebted to Mr. W. R. Dyson for his valuable help throughout.

* Revue de Métallurgie, vol. XV., pages 65 to 115; 1918.

LIMIT GAUGES FOR PLAIN CYLINDRICAL WORK.

A Conference on the question of limit gauges for general engineering work was held recently by the British Engineering Standards Association at the Institution of Civil Engineers, at which Sir Richard Glazebrook presided. The paramount necessity from a national point of view of a standard system of such gauges for general engineering work has been emphasised by the experience of the war. The immense amount of interchangeable parts required, owing to the abnormal demands made during the war has brought this question very much into prominence. With the return of peace it is realised that competition will be very strenuous. Repetition work is absolutely necessary, and if the manufacturers of the country can be persuaded to adopt a system of limit gauging, not only will the character of their work be improved, but their output will be increased. About 50 people were present, chiefly manufacturing engineers.

Two important points were brought out during the discussion, in fact they were thought by some of those present to strike the keynote of the situation. One laid stress on the necessity for publicity and educational work, and the other emphasised the importance of securing that any system recommended should be a development of, and not incompatible with, the systems at present in use in the various factories. This latter point it was felt would need careful investigation, there being little definite knowledge as to the number of firms throughout the country using systems which would be affected by a new scheme.

The Chairman stated that the Conference had been called together to gain some general idea of the views of the manufacturers as to the principles which should, in their opinion, underlie a system of limit gauging for general engineering work; to learn their own experience, and to discover by means of a properly organised investigation into the subject, how far they considered it would be possible to co-ordinate existing practices so as to evolve a standard system which could be used satisfactorily by all concerned.

The meeting discussed at length the following points: a general expression of opinion was asked for in each case, not as constituting a definite decision, but rather as affording some indication as to the trend of opinion in regard to the main points at issue:—

1. Should the hole or the shaft be taken as the basis. It was agreed that the hole should be the basis.

2. Disposition of limits.

Two main proposals were discussed: (1) That the mean dimension of the hole should be its nominal size, the tolerances being both positive and negative. (2) That the minimum dimension of the hole should be the nominal size, the tolerances being positive.

Apart from theoretical considerations, the choice of the mean size as the nominal was urged for the reason that as this system was already employed in the principal existing systems, it would be more likely to gain a general adoption than would the other. The voting, however, out of 46 present, showed 23 in favour of taking the minimum hole as standard, as against 16 in favour of taking the mean.

3. *Qualities of Work.*—The general feeling was that four or five qualities of work would be sufficient, qualities or work being taken to mean degrees of fineness of tolerance. Some present considered more to be necessary, others thought three sufficient.

4. *Classes of Fit.*—It was agreed that the following three classes of fit would be needed, *i.e.*, running fits, transition fits, and interference fits. It was emphasised, however, that it would not be necessary to arrange for all the qualities of work in each class of fit.

5. *Allowances.*—The question as to whether the basis of the system should be the minimum or mean allowance in the case of both running and obstruction fits received considerable attention, and was left for more detailed consideration.

As regards the basis for laying down tolerances and allowances for running and transition fits, it was agreed that further experimental work was needed before this could be finally settled, but the feeling was expressed that the formula:—

$$\text{Allowance} = a + b\sqrt{D}.$$

a and b being suitable constants, and D the diameter, might be accepted provisionally. In applying such a law the tolerance would naturally increase by a series of steps, its amount being constant over a given range of diameter, and increasing by some definite step at the end of that range.

It was generally agreed that for most qualities of work the steps should be limited to multiples of two or four ten-thousandth of an inch, while not excluding multiples of one-ten thousandths in the finer qualities of work, and the ranges formed by the series 0·1, 0·2, 0·3, 0·4——— of an inch were thought to be suitable for running and transition fits. It was thought that interference or obstruction fits should increase proportionately to the diameter.

6. *Procedure.*—The question has hitherto been considered by a Sub-Committee of the Sectional Committee on Machine Parts, their Gauging and Nomenclature, and at the close of the Conference, the meeting was asked as to whether it considered it would be desirable for a larger and more representative committee to be formed for the sub-committee to report to in order to obtain the widest publicity possible for the work and the fullest measure of support for the recommendations when issued. It was agreed that such a course would be beneficial as safeguarding all interests, and a scheme by which, pending the formation of this sectional committee, the present sub-committee should be reorganised with the addition of a number of manufacturing engineers, and given the power to appoint panel or small committees of experts to commence the detailed work, has now been sanctioned by the main committee of the Association, and is being put into operation.

The Journal of the Institute of Metals.—We have recently received a copy of the twentieth volume of the Journal of the Institute of Metals, which is published at the offices of the Institute at 36 Victoria-street, Westminster, London, S.W. 1. Though essentially a record of a series of meetings held during perhaps the most anxious period of the great war, the information it contains relates to peace conditions as well as to war work, and should be of great value in connection with the work of reconstruction. A feature of especial interest in the volume is the May Lecture on "The Formation of the Diamond," by the Hon. Sir Charles A. Parsons, which was reprinted in Engineering, vol. cv, page 485. Thirteen other communications cover a wide range of subjects of interest to metallurgists—such as the use of oil fuel in the foundry, grain growth in metals, the annealing of sheet aluminium, the properties of various non-ferrous alloys, and the scope of the works laboratory. The volume concludes with a large number of concise summaries of the world's metallurgical publications during the past half year, and reference to the whole of the contents is facilitated by a very complete index. The price of the volume is 21s. net.

Zinc and Spelter Joint Industrial Council.—The Interim Industrial Reconstruction Committee for the zinc and spelter industry has, with the approval of the Minister of Labour, been formed into a Joint Industrial Council. The first meeting of the Council was held at the London Chamber of Commerce on Tuesday, the 13th inst. After a letter from the Minister of Labour, recognising the Council as a Standing Consultative Committee to the Government on questions affecting the industry, had been read, the question of industrial diseases to which workers in this industry are liable, was considered by the Council. Dr. T. M. Legge, of the Home Office, attended the meeting, and dealt particularly with the prevention of lead poisoning and Bright's disease. He stated that there had been a substantial reduction in the number of cases reported during recent years, owing to the great structural improvements that had been made in the various works, but he admitted that the decline was much less than might reasonably have been hoped for, and he invited both sides in the industry to co-operate in reducing the causes of disease. He laid special stress on the vital importance of ventilation, as statistics showed that these diseases were almost entirely caused by the dust and fumes given off in the process of smelting.

Import Restrictions.—The President of the Board of Trade after duly considering the recommendations of the Consultative Council on Imports, has given the following further directions in regard to the Prohibitions of Import: The restrictions on the importation of the following articles are to be removed: Motor-car jacks and track jacks, files, bronze castings (machine or phosphor bronze), foundry flasks, springs for the upholstery trade, combination moulds and ladles, friction clutches, piercers, punches and round hole perforators, adjustable pipe tongs, flexible metallic tubing, food choppers or mincing machines (hand driven), bread-making machines (hand driven), bread and meat-slicing machines (hand driven), enamelled hollow-ware, steel ferrules. The importation of the following articles is to be licensed only exceptionally as and when required: Portable shop cranes, electric hoists and steel pulley-blocks except Yale triplex pulley-blocks and Yale triplex electric hoists which are to be rationed to regular pre-war importers at the rate of 100 per cent. of 1913 importations; all types of jacks except motor-car jacks and track jacks, crowbars, pinch bars or hand wagon movers, wire fence stretchers and strainers, steel barrows, steel tanks, trolleys and trucks for warehouse and wharf, Shaft bearings, shaft-bearing boxes, blocks for shafting, shaft collars, shaft couplings, shaft hangers, shaft-hanger frames: iron and steel pulleys, except pressed steel pulleys of which 200 tons (actual net weight) are to be admitted until September, 1 1919; fan blowers and forges; metal baths and fittings thereof; cast-iron pipe fittings and cast-iron pipes, rainwater pipes and soil guttering pipes in so far as at present prohibited; aluminium hollow-ware; iron and steel welded tubes up to 2 in. in diameter. The importation of the following articles is to be restricted as shown: rubber tyres are to be admitted at the rate of 50 per cent. of 1913 importations; sewing machines (domestic hand and treadle) and parts thereof are to be admitted at the rate of 75 per cent. of 1913 importations; zinc oxide is to be admitted up to 50 per cent. of 1913 importations. This is an amendment of the decision already published. Applications for special licences should be made as usual to the Department of Import Restrictions, 22, Carlisle Place, London, S.W. 1.

ON THE SOLID AND LIQUID STATES OF STEEL.*

By COSMO JOHNS, F.C.S., F.G.S., M.I.Mech.E.

INTRODUCTION.

THERE are only three states known in which matter can exist—namely, the solid, liquid, and gaseous. It is true that references abound in scientific and technical literature to a supposed "amorphous" state, but evidence has accumulated which makes it clear that this is not a state distinct from the three already mentioned, but is always a modification of either the solid or liquid forms, or possibly a mixture of both. It is the object of this communication to make clear so far as possible the difference between the solid and liquid states in the case of steel, and to point out the necessity for observing such distinctions if progress is to be made in the scientific study of that most important constructional material. It will only serve still further to emphasise the need for further study and still more careful observations if the illustrations are selected from everyday occurrences in any and every steel works. Only rare allusions have been made in the literature of steel to the gaseous phase of that metal, though there is abundance of evidence that molten iron has an appreciable vapour pressure at the temperature employed in the open-hearth melting furnace. The vapour of iron as it rises is rapidly oxidised by the furnace gases to magnetic iron oxide, the only stable form at high temperatures, and not only permeates the refractories which line the furnace, but also falls as a mist of rain of minute globules of molten oxide on the surface of the slag present, thus profoundly affecting the direction of the reactions that take place. A clean silica rod or other object would be coated, in the course of half an hour, with a film of oxide 5 mm. thick. Interesting and important though the vapour phase may be, its discussion at any length is outside the scope of the present lecture, and the subject will only be referred to incidentally when describing the surface phenomena of liquid steel. It will assist in avoiding ambiguity of expression, and thus tend to clearness of thinking, if we define with some approach to exactness the substance we are dealing with and the particular states of that substance which we propose discussing. Many attempts have been made to define "steel," but with very limited success, for each attempt was followed by demonstrations that striking exceptions existed. It is now proposed to define steel as "iron to which appreciable quantities of some element, or elements, have been added during manufacture for the specific purpose of modifying, or adding to, its desirable properties." It will be interesting to note whether this definition will escape the fate of previous attempts in the same direction. It will be useful to mention that in the present paper the accepted definition of a solid, that it is a "crystalline aggregate," will be employed. Now, as a crystal is a body whose atoms are oriented according to a definite system, the accepted definition of the change from the solid to the liquid state can be stated as follows:—When by the application of heat, with or without a change of pressure, the atoms of the crystals composing the solid substance cease to be oriented, that particular substance no longer exists as a solid, and has acquired new and distinctive properties. It may still possess considerable rigidity; it may be unable to flow under the influence of gravity; it may still retain the outward appearance of solidity, but it has suffered a profound alteration, and exists in a new state, the recognition of which is important. This is the glassy or vitreous modification of the liquid state to which the term "amorphous" is often applied. It is much better to speak of it as vitreous in the sense used by Beilby, who has contributed so much to our knowledge of this modification of the liquid state of metals. Strictly speaking, it is an undercooled liquid with the rigidity of a solid, but in other respects possessing the properties of a liquid. It might be disturbing to have to consider ordinary glass as an undercooled liquid, but to define it as a solid substance would create more difficulties than would be avoided. When the substance can flow under the influence of gravity, as most liquids do, there is no difficulty in accepting the definition of the liquid state.

THE SURFACE OF LIQUID STEEL.

If a stream of acid steel be observed as it flows from the launder of an open-hearth furnace into the ladle, or from the lip of a crucible as it is poured into a mould, and if care be taken to select that portion which is free from oxide films or slag, it can be seen under suitable conditions that the surface of the pure metal has very definite properties. Many must have observed a difference in the intensity of the heat radiated when the first flush of slag comes as the flow of steel decreases. The heat radiated is much greater, though it is certain that the slag and steel so closely following each other must be at the same real temperature. From this we learn that liquid acid open-hearth slag and steel of the same real temperature radiate differently, and that the heat emitted by different bodies in the open air do not indicate their true temperatures. When the conditions are suitable the stream of steel can be seen to reflect the sunlight as brilliantly as many mirrors, and the light from an electric arc light is also reflected when suitably placed. No such reflection takes place from a surface of liquid slag, and thus liquid slag and liquid steel are illustrations of the truth that good reflectors are bad radiators even when they are in the same—in this case both liquid—state. But if we follow our liquid steel until it has been poured into a mould, and the free radiating exposed surface observed, it will be found that at the moment of solidification there is a marked rise in the intensity of the heat radiated. This can be better observed with copper, which is usually cast into open moulds, and allowed to freeze or solidify with its upper surface exposed to the atmosphere. Here the increase in the intensity of the heat radiated is most marked, and is sufficient to cause a change from comfort to extreme discomfort on the part of an observer standing near if a large surface is exposed. We thus learn that not only do different substances at the same true temperature emit heat varying in intensity, but that the same metal will radiate heat with more intensity when it has just solidified than it did when in the liquid state. This phenomena has been explained as due to a real rise in temperature as the metallic mass passes from the liquid to the solid state, but though this actual rise in temperature might occur under certain circumstances owing to undercooling, it falls very far short of explaining the great rise in the intensity of the heat radiated in the cases mentioned. That some other cause must be sought for will become clear when we observe an ingot of steel at a temperature much below its melting-point passing through the rolls of a cogging mill. During the early passes the coating of scale falls off, and the intensity of the light or heat radiated can be measured by suitable pyrometers. It is found that the newly-exposed surface of the steel radiates almost as a black body. Its emissivity is 0·97, which is near enough to unity for the readings of an optical pyrometer to be taken as true temperatures. The surface of solid steel is therefore an exceptionally good radiator. It is not without significance that no reflection of sun rays or electric lights can be observed from the freshly exposed surface of a steel ingot even immediately after its coating of scale has fallen off. Before discussing further these differences, however, it will serve some useful purpose if we consider further the nature of the surfaces we have been observing, and thus to be certain whether we are or are not observing the pure metallic surface. Now, the higher the temperature, the more rapid the oxidation of steel, so we should expect the greatest difficulty to occur when observing a stream of liquid steel. Careful observation with an optical pyrometer, and even, sometimes, with ordinary blue glass, reveals the occasional presence of brighter-looking patches of oxide film on the surface of the swiftly-flowing steel, but these are chiefly on the upper turbulent surface. If the side of the stream be observed as it leaves the launder it can be seen to be an optically clean metallic surface, and this oxide-free surface is preserved for a considerable distance down the stream—and the question arises as to how this pure metallic surface of liquid steel is preserved from oxidation during its exposure to the oxygen of the atmosphere. It is to the existence of a vapour phase that this must be attributed. The constantly renewed layer of iron vapour suffers oxidation itself in its outer layers, but its presence serves to preserve the surface of the liquid steel from contamination with oxide. In the case of the steel solidifying in an open mould, this evolution of vapour ceases when the metal becomes solid, and the surface oxidises instantly. It is the high emissivity of iron oxide that explains the greater intensity of the heat radiated when liquid steel passes into the solid state. The ingot of steel at the usual rolling temperature, whose freshly exposed surface was found to possess such a high degree of emissivity, was coated with a layer of dewly-formed oxide. Solid steel possesses no effective vapour pressure; its metallic surface at rolling temperatures is instantly oxidised, and it is the oxide and not the metallic surface that we were observing. If, however, we take a plane surface of solid steel and polish it carefully, we do get a fairly effective mirror which will reflect light, and does not act as a good radiator of heat. But Beilby has shown by his experiments on polished surfaces of metals that the polishing has caused a profound change in the polished surface—a change that can only be explained by the assumption that the extremely thin surface layer has been actually fused, and has flown over and filled the surface depressions, and that this thin fused surface layer, owing to its rapid cooling, due to the cold metallic mass which underlies it, has not had time to crystallise, and is therefore not truly in the solid state. It is in the vitreous or undercooled liquid form, very rigid, it is true, and hard too, but nevertheless possessing the properties of a liquid. It behaves when reflecting light just as the optically clean surface of liquid steel does.

THE SURFACE TENSION OF LIQUID STEEL.

The term surface tension has been used to describe those forces acting on the surfaces of liquids which act as if it were an elastic membrane. The action of these forces can easily be observed by pouring mercury on some plane surface of a material it does not wet. The globules can be made to roll about, and though in form they are not perfect spheres, they retain considerable rotundity, and obviously resist the effect of gravity. If two globules touch each other they coalesce to form one larger one, and an appreciable amount of force must be used to break the large globules into smaller ones. It is to this energy, acting on the surface of liquids, tending to alter their form to that offering the smallest possible surface, that the term surface energy has been applied. This surface energy or surface tension can be measured by appropriate means, and the values obtained vary for different liquids. These values are constants for the same liquid under similar conditions, but they would vary if the purity or other condition of the experiment varied. Now, liquid steel has a surface tension value comparable with that of mercury, but the determination of that value involves greater experimental difficulties than is the case with a metal that is liquid at room temperature. But, though quantitative values are not easy to obtain, it is not difficult to demonstrate the existence of surface energy qualitatively. The small samples of liquid steel with a protective coating of slag which are withdrawn from steel-melting furnaces for testing purposes offer opportunities for observing surface tension effects. They are best seen with acid steel where the conditions are favourable for establishing equilibrium between the steel and slag, and where the progress made towards the equilibrium can be conveniently followed. It is true that the sample can only be explained after solidification has taken place, but, as the solid sample retains the form it possessed in the liquid state, this introduces no difficulty, while there are considerable advantages. It should be made clear that high or low values for the surface tension of liquid steel are no criterion of the usefulness of the steel. For some purpose a steel with a high value is desirable, but for another class of product it would be most undesirable, and low values are, in practice, aimed for. The purpose of this discussion is not to indicate the type of steel most suitable for certain products—that has been decided in practice many years ago—but to describe observations that have been made, and to offer a reasoned explanation. It often happens in the relations of science and industry that some scientific truth has been discovered, and that many years have elapsed before it was applied to explain observations made by practical men in the course of industrial operations. Experienced melters have for years referred to the "skin" of the samples they take. They know that under certain conditions marked skin effects can be observed. That liquid steel behaves as if it had a skin is only to show that it behaves in the same way as mercury. To call the energy which has this effect on liquids surface tension is but a further step in knowledge, but it does possess the advantage that this knowledge is now exact; it is no longer empirical, and the way for further advances is made more clear. The literature of the metallurgy of steel contains few, if any, references to its surface tension, yet the workmen had not overlooked the phenomena, and, knowing nothing of the advances made in pure science, had succeeded in giving a name to what they observed, which would have appealed to the worker in pure science as illuminating and suggestive, but which seems to have failed to arouse the interest of the earnest, but not always well instructed, prophets of the new metallurgy, who think that they best serve the interests of industry by ignoring the progress of pure science, and confining their attention to "applied" science, which too often is not science at all. The appearance of the upper surface of the samples referred to above, changes in a marked manner as deoxidation proceeds. At first they are flat or distended with gases liberated at the moment of freezing, but as deoxidation proceeds the skin effect asserts itself, gases are no longer liberated, and the edges of the sample become rounded and the upper surface smooth. While it was flat dendrites were visible on the surface, and even when the greater portion of the upper surface of the sample has become smooth and rounded there will still remain a small depression to which the slag closely adheres, but which, if exposed, exhibits dendritic markings, indicating that the surface energy has not yet reached its maximum value. A later stage may be reached when the sample is fully rounded; dendrites are absent from its surface, and its contours are similar to an equal mass of mercury in the same mould. The surface is not only smooth, but, if the slag conditions are suitable, and cooling can be effected without access of air, bright and even mirror-like. It will reflect light just as the polished surface of steel did. There are no signs of crystals or crystallites on that surface, yet, if the sample be sharply broken, the interior is seen to be unquestionably crystalline. The surface or skin, under the effect of surface energy, has failed to crystallise. The forces operating at the surface have been greater than those which directed the marshalling of the interior atoms to form the constituent crystals of the metallic mass. "The skin is not in the solid form; it is vitreous, an undercooled liquid." A further stage may be reached where the presence of a skin or vitreous surface layer is still more clearly evidenced, when the directing crystalline forces operating in the interior have palpably failed to overcome the surface energy effect, and the skin of the solidified sample can be seen wrinkled like a dried bean as it endeavoured to accommodate itself to the contracting interior. These wrinkles, like the waves of an instantly frozen sea, are sometimes coarse, sometimes fine. It may be possible to obtain a value for the surface tension by measuring the distance from crest to crest, but much more work must be done before we completely understand the forces operating. Of the methods available for obtaining quantitative results, the capillary and drop method can be discarded at present, owing to experimental difficulties naturally attendant when temperatures such as that of liquid steel are being dealt with. The solidified drop method is promising, though the difficulties of obtaining drops or globules which have solidified without any constraint other than that of gravity and surface energy are considerable in the case of steel where the access of oxygen might invalidate the results. The few determinations that have been made indicate a value for steel considerably greater than that of mercury. It is perhaps more interesting to discuss now the reasons for the variations in the surface tension which are apparent, if not measurable, as the samples progress towards a more complete state of deoxidation. It is known that the occluded gases found in steel profoundly affect its properties when in the solid state, so it was of some interest to determine whether the volume of the occluded gases had any relationship to the qualitative values found for the surface tension. As a result of a number of determinations it was found that the volume of the occluded gases was inversely proportional to the surface tension value. At first sight it would appear that this was a clear case of cause and effect, but when it was found

* Being the substance of a lecture delivered in the Royal Technical College, Glasgow, on Friday, December 2, 1918, to the members of the West of Scotland Iron and Steel Institute.

that the increase in volume was due to the presence of a larger quantity of the oxygen compounds CO and CO_2 in the occluded gases, it seems preferable to attribute the rise in the surface tension to the gradual elimination of dissolved iron oxide, so that both the increased volume of gaseous oxygen compounds in steel and the lowering of the surface tension are the effect of the same cause, namely, the presence of dissolved iron oxide. With the elimination of the dissolved iron oxide the surface tension value rises, and the occluded gases diminish in volume. Thus the "killing" of steel is not only evidenced by the change in its properties when in the solid state, but its progress can be noted by the rise in its surface tension value, and when experimental methods of the required degree of accuracy are available it may be measured in comparable terms, and possibly as accurately as the surface tension of other liquids.

EFFECT OF UNIFORM PRESSURE ON CHANGES OF STATE.

The effect of pressure on changes of state is taken but rarely into account when metallurgical questions relating to steel are discussed, and its importance is generally overlooked. Yet we have available a number of facts and inferences; carefully devised experiments have been made, while the principles operating are clearly defined and their validity is unquestioned. Metallurgical operations are often directed towards causing a change of state. Solid metals are fused, or the liquid is rendered solid; a change from one allotropic state to another is induced, and its inversion prevented or retarded. These changes always involve an alteration in volume, with the result that great variations in pressure occur which have important consequences in practice. It is only proposed here to deal with the principles involved and their application to a few typical cases, so that their importance might be recognised, and the distinction between the solid and liquid states rendered more clear. The effect of uniform or hydrostatic pressure—that is, cubic compression—is to raise the melting-point, to quote a typical change of state, for all substances except water, gallium and bismuth. These exceptions are significant, for both instances are exceptional in that they expand on passing from the liquid to the solid state. These three exceptions prove the general rule, that substances which contract in volume on freezing have their melting-points raised, while those which expand on freezing will have their melting-points depressed. Extreme pressure will cause ice to melt, and the melting-point of bismuth is appreciably lowered if the metal be subjected to pressure. The rule applies to the effect of uniform pressure only. Unequal pressure, involving shearing stresses and consequent permanent deformation, will be discussed later. So far only melting points have been mentioned, but the rule also applies to other changes of state, and, provided that the direction of the volume change is known, it can be predicted whether the change point will be raised or lowered by pressure of the nature assumed in the discussion. The application of the rule to steel will become apparent when it is pointed out that a mass of steel cooling through the critical range, when the change from one allotropic form to another takes place, involves a momentary but appreciable increase in volume; it will be seen that we have a change of state that will have its change point depressed if pressure be applied. Now pressure, in fact considerable pressure, is applied when steel is quenched from its correct hardening temperature, for the volume of steel is greater, and its density consequently less, at high temperatures than low. The momentary increase in volume when cooling through the critical range is but an interruption in the curve of decreasing volume. Quenching has the effect of retaining the steel in its high temperature or metastable state—(1) by the rapid increase of viscosity due to the sudden cooling, (2) owing to the pressure exerted on the interior by the cooled outer layers. Roberts-Austen used a hydraulic press, and also made quenching experiments which demonstrated that the steel in the interior of the mass underwent its allotropic change at a lower temperature, as a result of the pressure applied, as it should from theoretical considerations. The allotropic change involves the momentary de-orientation of the atoms, and this, if the quenching proceeds rapidly enough, might result in a number failing to adjust themselves to the new orientation before the viscosity had increased too much to permit this, and thus a portion of the steel would remain uncrystallised and be in the vitreous or undercooled liquid state. The existence of a vitreous cement at the boundaries of the crystals is now, as a consequence of the experimental work of Beilby, assumed as the basis of a widely-held hypothesis, which so far holds the field. The amount present of this vitreous cement will probably vary with the rate of quenching, and it will certainly vary as the grain size increases or decreases. With under-cooled silicates it has been shown that heating them causes crystallisation, and thus the change to the solid form. This necessarily involves the liberation of the heat of fusion; for the undercooled liquid has never, by definition, become solid. It is significant that Cloup found an irreversible evolution of heat at 400 deg. C. when reheating a quenched steel. This, in itself, would not amount to a rigid proof; but he also found the same thing to occur when he reheated a piece of cold-worked steel, and this, as will be seen from the succeeding section, is most important evidence. For the present it will suffice to state that there is evidence that the solid and liquid states of steel are present in a sample at ordinary room temperatures. The spontaneous evolution of heat, noted by Brush, Hadfield and others in the case of quenched steels is but another proof that steels in this condition are in a metastable state. The evolution of heat that Cloup found on reheating such steels represents a further stage in the progress towards a stable state, and indicates relief of the stresses induced by quenching. These stresses are pressure effects, and the evolution of heat, whether spontaneous or as a result of reheating, is a measure of their intensity. The not uncommon fracture, internal or external, of masses of steel when heated or cooled too quickly is another result of the stresses developed.

THE EFFECT OF NON-UNIFORM PRESSURE ON CHANGES OF STATE.

In discussing the effect of non-uniform pressure, attention should be drawn to the work of Johnson and Adams in clearly distinguishing between the effect of uniform, or hydrostatic, pressure, with which we have so far been dealing, and unequal pressure involving shearing stresses. The distinction is fundamental and of importance when considering the permanent deformation of metals. These writers assume that permanent deformation of a crystalline aggregate, or solid, is due to an actual fusion of a minute portion of the mass along the planes of shearing, with subsequent solidification. But as this re-solidification must occur with extreme rapidity, owing to the abstraction of heat by the surrounding cold mass, there is ample opportunity for formation of a certain amount of super-cooled or undercooled liquid, corresponding to Beilby's vitreous phase, to act as a cement between the distorted or ruptured crystals. This would result in the conversion of the original metallic mass into a conglomerate, with a new pattern in which the extent of the boundaries would be increased, and containing a larger proportion of the vitreous or undercooled form, with a consequent profound change in properties. Non-uniform pressure always lowers the melting-point. That non-uniform pressure should suffice, during the permanent deformation of a solid metal, to cause actual melting of even the minute particles carrying the excess load is admittedly a startling assumption; but the thermodynamical proof is admitted by Roozeboom, Ostwald, Le Chatelier, and Nernst, and only questioned by Tamman. It would appear that the views of Johnson and Adams have considerable support. An ordinary compression test on a short cylindrical-shaped piece of steel affords some experimental evidence. When sufficient pressure is applied permanently to deform the test-piece to, say, half its original height, not only will it have suffered a change of form, but it will have changed its properties. Its tenacity will have increased, its elastic limit will now be higher, it will be less dense, and on reheating an irreversible evolution of heat will occur, as was found by Cloup, at 400 deg. C. This can all be explained on the assumption that a local melting of a small proportion of the permanently deformed material takes place, and that a portion of the melted material is preserved in the vitreous or undercooled state. Without this assumption it will be difficult to find a convincing explanation.

SUMMARY.

1. The properties of an optically clean surface of liquid steel are described, and the similarity to that of a polished metallic surface with a vitreous film pointed out. The preservation of this surface of liquid steel is attributed to the presence of an atmosphere or iron vapour.

2. Means by which the surface tension of liquid steel can be determined qualitatively are described, and it is pointed out that the surface tension value varies inversely with the volume of gases occluded. It is also suggested that the iron oxide dissolved in the steel is the factor which causes the variation both of the surface tension value and of the volume of occluded gases. The occurrence of a film of vitreous or undercooled steel on the surface of a sample of liquid steel, if the surface tension value be high, which has solidified out of contact with any oxidising agent is described.

3. The distinction between the solid and liquid states is emphasised, and it is shown that fluidity, or the ability to flow under the influence of gravity, is no criterion of the liquid state.

4. The effects of uniform and non-uniform pressure are described, and the difference shown to be fundamental. The former raises the melting or other change-point, except in the case of water, gallium and bismuth. It is shown to follow the general rule that uniform pressure depresses the change point which would have resulted in an increase of volume, and raises it if it would have resulted in a decrease in volume. The importance of this in the quenching of steel is pointed out.

5. Non-uniform pressure always depresses the melting-point. An actual fusion of a small portion of a metallic mass undergoing plastic deformation is assumed, and the authorities quoted, and shown to be capable of explaining the known facts.

A SHORT BIBLIOGRAPHY.

This brief list of works relating to the problems discussed in the paper is obviously not exhaustive, but it will serve as an introduction to the study of the solid and liquid states of matter for those interested in the subject:—

Poynting and Thomson. "Properties of Matter." Charles Griffin and Co., Limited, London. The best introduction to the subject.

Johnson and Adams. Am. Jour. Sci., vol. XXXV, pages 205 to 253, March, 1913. An important discussion of the effect of high pressure on the physical and chemical behaviour of solids, with very complete references.

Wheeler. Am. Jour. Sci., vol. XXXII, pages 85 to 100, August, 1911. Discusses the reflection of light at metal-liquid surfaces.

Willows and Hatschek. "Surface Tension and Surface Energy." J. and A. Churchill, London. A useful introduction to the study of surface tension.

Johnson and Adams. Am. Jour. Sci., vol. XXXI, pages 501 to 517, June, 1911. Describes experimental work on the effect of pressure on the melting-point of metals.

Day, Sosman and Hostetter. Am. Jour. Sci., vol. XXXVIII, pages 1 to 39, June, 1914. Discusses volume changes of solids with variations of temperature, and makes an important revision of the classic work of Carl Barus on the volume of solid and liquid diabase.

CATALOGUES.

Steam Plant.—Messrs. Ed. Bennis and Co., Limited, Bolton, send a copy of the bound volume for 1918 of their periodical *Cheap Steam*. It contains a good deal of useful information of a practical kind, clearly expressed; and with the slightest exceptions strictly relevant to steam plant.

Wood-Working Machines.—Some little time ago we published some notes on an excellent and comprehensive catalogue of wood-working machines by Messrs. Thomas Robinson and Sons, Limited, Rochdale. We are now pleased to receive a new compilation of this information with the text printed entirely in French and specially prepared for the Lyons Fair.

Triplex Glass.—The Triplex Safety Glass Company, Limited, Hythe-road, Willesden, N.W. 10, send a booklet entitled "The War Record of a Wonderful Invention," which gives a most interesting account of the many uses of their product in the war. Wind screens, goggles, port holes, submarine periscopes, and motor-car windows were amongst the many uses to which it was put. Its extraordinary power of receiving heavy blows without splintering has undoubtedly made it one of the most useful and life-saving of minor inventions.

Milling Machines.—The classification of these machines into horizontal and vertical gives little indication of the real variations of construction. In a catalogue received from Messrs. James Archdale and Co., Limited, Birmingham, there are many forms in each class, from powerful machines with 18 speeds and nine feeds to what is known as a manufacturing machine with one speed and specially adapted for a limited range of rapid repetition work. The designs make for simplicity with great strength and powers of heavy cutting and quick change of work-piece. One result is the distinctly pleasing form of the main castings, and the ingenuity with which the operating hand wheels and levers are brought within easy reach and without confusion. Some very fine specimens of milling cutters are shown.

Ships and Airplanes.—A modest booklet in brown paper binding entitled "Four and a half Years War Work," comes from Messrs. Barclay, Curle and Co., Limited, Whiteinch, Glasgow. The summary of it is 57 ships totalling 217,000 tons built and engined, 80 sets of main engines and 156 boilers of 212,000 i.h.p. This noticeable approximation to 1 h.p. per ton is a singular result of averaging very various vessels including 12 merchant ships ranging from 14,000 tons to 3,600 tons, 30 sloops of war all near 1,400 tons and 6 oil tank ships, including 2 of 15,900 tons each and 2 of 2,000 tons each. The firm also built some 500 air and sea planes of various types, and the heavy complement of spare parts required for these delicate structures. The record is highly creditable to the firm. It has also another significance: it is a specimen record of the characteristic quality of our large, well-established and well-organised British engineering works. The variety of work in ships, engines and boilers alone is quite beyond the capabilities of any one firm amongst our foreign competitors. This marks the difference between the British engineer and the foreign manufacturer. The airplane work was pressed on the firm because the capacity for organisation and the faculty for new tasks was there; just as the same work was pressed on other firms mainly famous for agricultural engines and steam road locomotives. This side of the question is overlooked by many of those who have so much to say in praise of cheap manufacture. The British method leaves us a national possession in the quality of employers technical staff and workmen. It gives us the man as well as the product. If it serves our most desperate need in war it may have some merits in peace.

MICROSTRUCTURE OF IRON IN ELECTRIC WELDS.—Last year Mr. S. W. Miller contributed a paper to the American Institute of Mining Engineers on "Structures in Steel Fusion Welds," during the discussion of which various conflicting opinions were expressed as to the nature of the small needle crystals observed in oxy-acetylene and electric welds. The discussion induced Mr. F. G. Comstock of the Titanium Alloy Manufacturing Company, of Niagara Falls, further to examine a weld made on a piece of steel plate, $\frac{1}{4}$ in. thick, on which iron had been deposited to a depth of $\frac{1}{16}$ in. by arc welding; the weld appeared very good, and did not show any boundary between the plate and the iron. Sections were cut in three planes at right angles to one another through the deposited metal and the steel plate underneath. The polished sections showed round gray oxide spots and after etching with nitric acid also the pale needle crystals of what Miller regarded as cementite, Jeffries as martensite, and Ruder and Boylston as iron nitride. Under the microscope the boundary between the steel and iron became sharp; the steel immediately underneath the weld appeared coarse-grained, lower down it was finer. Small sections were then cut; the one was annealed at 500 deg. C. (*i.e.*, below the critical temperature of the steel), and the other at 900 deg. (above that point); the former was cooled in lime, the latter slowly cooled in the furnace. The fine micrographs of the sections obtained are reproduced in the January Bulletin (of this year) of the Institute. Analyses of filings were also made, and as only 0·04 per cent. of carbon was found, Comstock concludes that the pale crystals cannot be cementite or martensite, but are probably iron nitride. This conclusion is supported by etching tests made with sodium picrate and by the detailed study of the micrographs which indicated that the needles when slowly cooled after annealing diffused into the steel, but did not merge into the pearlite of the steel. Direct evidence in favour of the nitride formation is however, not given.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

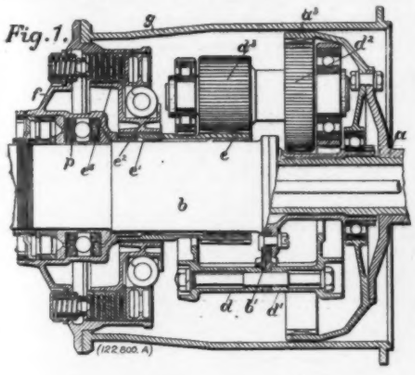
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

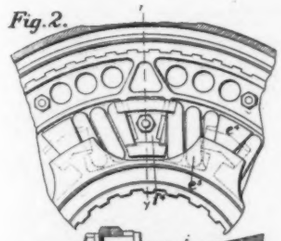
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

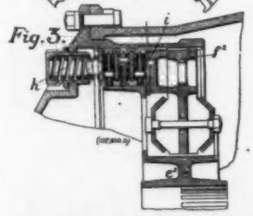
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

GAS ENGINES, PRODUCERS, HOLDERS, &c.

122,800. F. H. Royce, Derby, and Rolls-Royce, Limited, Derby. Internal-Combustion Engines. (3 *Figs.*) September 12, 1918.—This invention relates to epicyclic gear such as is sometimes interposed between the crankshaft and propeller shaft of internal-combustion engines for aircraft. *a* is the crankshaft to which is bolted the internally-toothed annulus a^5. *b* is the propeller shaft to which is fixed the flange b^1. The planet cage consists of two parts *d*, d^1, bolted to the flange b^1 carrying three equally-spaced planet wheels d^2 (which mesh with the annulus a^5) and toothed pinions d^3; *e* is the sunwheel carried on the propeller shaft *b*; e^1 is an extension of the sunwheel non-rotatably connected to the sunwheel carrier e^2 by means of interlocking serrations. On the sunwheel carrier e^2 are lugs e^4 recessed to receive coil tangential springs e^5, and having formed thereon pins to locate the springs. *f* is a bearing housing attached to the casing *g*, provided with a drum-shaped extension which carries the member f^2, to which it is non-rotatably connected by means of interlocking serrations, and on which member are formed

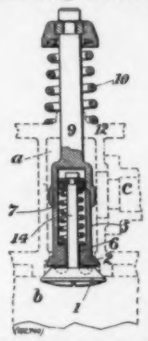






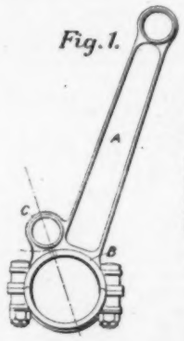
lugs f^4 projecting inwardly between the lugs e^4, likewise recessed to receive the other ends of the tangential coil springs e^5 and provided with plates carrying tongues to locate the springs. e^6 is an extension of the sunwheel carrier terminated in a drum-shaped part, on the external circumference of which are longitudinal serrations. On the interior of the drum-shaped extension are longitudinal serrations. Engaging with the extension e^6 are internally-serrated friction discs, which are faced with other discs of friction material and engaging with the drum-shaped extension are externally-serrated friction discs. A number of springs *h*, carried in pockets screwed into the housing *f*, press the discs into close engagement through the medium of a distributor pressure plate. *i* is a distance-piece occupying the space between the member f^2 and the friction discs, preferably faced with a steel rubbing disc. The reaction of the springs is received at the other end of the extension by a split ring let into a groove into the drum-shaped extension. A roller bearing supports one end of the propeller shaft, the other being carried in a ball bearing. A ball thrust bearing *p* transfers any axial load upon the propeller shaft to the bearing housing *f*, and thence to the gear-case *g*, which is bolted to the engine crank-case. (*Sealed.*)

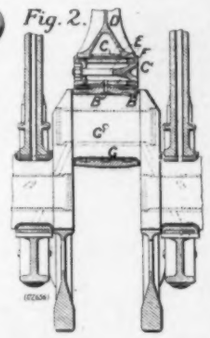
122,740. J. Russell, Hot Wells, Bristol, and R. Kennedy, Junior, Glasgow. Internal-Combustion Engines. (1 *Fig.*) March 21, 1918.—This invention relates to valves for controlling and regulating the feed of liquid fuel to the mixing and combustion chambers of internal-combustion engines of the type comprising two valves which are associated as one appliance and adapted to work in co-operation with respect to one another. The dotted lines at *a* indicate the valve chamber and at *c* the passage leading from the liquid fuel supply chamber to the valve chamber, whilst *b* is the mixing chamber. The new valve is a duplex valve, there being an inner valve 1 and an outer valve 2. The inner valve consists of a disc with spindle 14, which extends into the hollow stem 5 of the valve 2. 6 is a guide hole made in the valve 2 for the passage of the spindle 14, whilst 7 is a spring which bears against a washer on the spindle 14 and against the bottom of the hollow stem 5. Screwed to the hollow stem 5 is a spindle 9, which is acted upon by a spring 10 bearing against a washer on the spindle and against the valve casing 12. This



spring, in conjunction with the spring 7, tends to keep both valves closed tightly against their seats. The means by which the spindle 9 is moved to open the duplex valve may be means such as is ordinarily employed, namely, a camshaft or cams, pusher rods or rocker arms, or other well-known devices. When, in the working of the engine, the spindle 9 of the valve 2 is acted upon, at intervals, to cause the fuel to be delivered into the mixing chamber *b*, the valve 2 is moved off its seat and is brought to bear against the valve 1 and push it off its seat so that a free passage for the fuel is established. On the rebound of the spindle 9 under the action of the spring 10, the valve 1 reaches its seat (owing to the action of the spring 7) before the valve 2 is closed, with the result that the valve 2 is protected by the valve 1. (*Sealed.*)

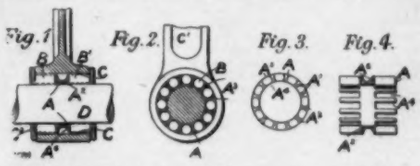
122,656. H. R. Ricardo, London. Internal-Combustion Engines. (4 *Figs.*) July 5, 1917.—This invention relates to connecting rods more especially engines of the V-type in which the connecting rods from two pistons run to a common big-end formed on one of these rods, has for its object so to form this big-end as to improve the connection between. The main connecting rod A is constructed with a big-end B. At one side of the rod A a lug C is formed, this lug being positioned centrally with respect to the axial width of the big-end B. The auxiliary connecting rod D has one end forked, the two members of this fork being adapted to lie on either side of the lug C. The forked end of the auxiliary rod is coupled to the lug C by a floating pin, which comprises a hollow cylindrical member E having one end closed and an external flange formed on this end. A bolt F having a flanged end or head is passed through the hollow member E, whose open end is closed by the head, the flange of which extends beyond the periphery of the pin E. The end of the





bolt is carried through a central opening in the closed end and drawn up by a nut. A radial passage B1 is formed through the big-end B and lug C into the opening in this lug through which the coupling pin E is passed. A corresponding passage is formed in the bushing C1, and a similar opening leads through the wall of the hollow pin E into its interior. Towards each end of the hollow pin E passages are formed through the wall of the pin so that lubricant can find its way from the interior of the pin to points situated about the centre of the width of the bearing surfaces between the hollow pin E and the fork arms of the auxiliary rod D. The lubricant, which is preferably supplied under pressure, flows through passages into the interior of the hollow crank-pin G, whence the oil finds its way through a passage G1 to the oil passage B1 in the big-end B and the central part of the pin E within the lug C. Thence oil can pass into the hollow coupling pin E and so to the bearing surfaces towards the ends of this pin. (*Accepted February* 12, 1919.)

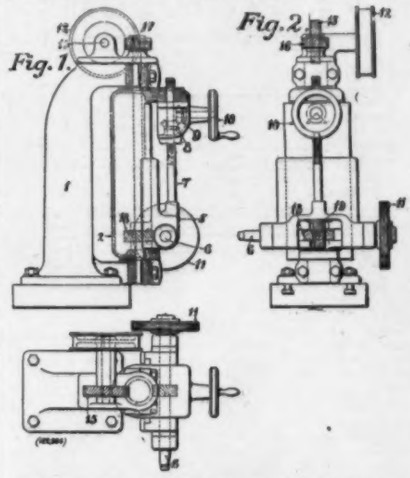
122,559. Triumph Cycle Company, Limited, Coventry, and G. E. Stanley, Coventry. Internal-Combustion Engines. (4 *Figs.*) May 10, 1918.—This invention is for improvements in the connecting-rod bearings of internal-combustion engines. According to this invention, a roller bearing for a connecting rod comprises in combination, an outer race integral with the connecting rod, an inner race integral with the member to which the connecting rod is operatively connected, a housing which carries two sets of rollers arranged side by side with the axes of one set in line with the respective axes of the other set, and is in the form of an annular flange which separates the two sets of rollers and carries on each of its side faces projections to space apart and support the rollers of each set, and means (for example, washers at the end of the outer race, or shoulders constituted by the supports for the inner race-carrying member) to retain the rollers endwise within the housing. The housing A for the rollers consists of a hollow cylinder whose walls are of a thickness somewhat less than the diameter of the rollers B, B_1, employed in the bearing. From each end of the cylinder A a series of recesses are drilled longitudinally of the cylinder axis, of a depth somewhat less than half the length of the cylinder, and of a diameter to rotatably receive the rollers B, B_1, therein. By thus limiting the depth of the recesses a portion of the housing A is left constituting an annular flange A_2, which serves both to support the side walls A_3 of the recesses and to separate endwise the two rows of rollers B, B_1. It will be seen that as the walls of the cylinder A are of less



thickness than the diameter of the rollers B, B_1, gaps A_4, A_5, in the inner and outer surface of the cylinder are produced in forming the recesses A_1. Through these gaps the peripheries of the rollers B, B_1, project to bear upon the outer race C formed integral with the connecting rod C_1, and the inner race, constituted by the pin (in this example the crank-pin D) with which the connecting rod is operativley engaged. When the bearing with its housing and rollers is assembled, washers C_2 may be applied at the ends of the outer race C to prevent endwise displacement of the rollers or housing. These washers C_2 may be secured to the connecting rod, or may be loose on the crank-pin D, and retained in place against the connecting rod by the crank-discs or other part adjacent to them. (*Sealed.*)

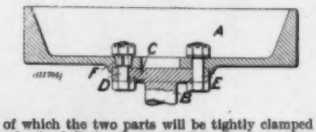
MACHINE AND OTHER TOOLS, SHAFTING, &c.

122,804. The Churchill Machine Tool Company, Limited, London, S. H. March, Chorlton-cum-Hardy, Manchester, and H. H. Asbridge, Pendleton. Grinding Machines. (3 *Figs.*) October 15, 1918.—This invention relates to grinding machines of the type known as universal machines, where it is necessary that the spindle carrying the grinding wheels be adjustable in the vertical plane, in addition to swivel adjustments in the horizontal plane as required for the work. 1 is a standard with machined base so that it may be attached to the respective machine slide on which it is intended to be used. The swivelling column 2 is provided with trunnions at its upper and lower ends respectively, and supported in bearings in the standard 1. The spindle head 5, which carries the grinding wheel spindle 6, is supported on the column 2, and is vertically adjustable on the



same by means of a screw 7, bevel wheels 8 and 9, and hand wheel 10. The grinding wheel 11 is shown in position on one end of the spindle 6. The drive to the grinding wheel spindle is by a belt, driving on to a pulley 12 on a shaft 13. On the other end of the shaft 13 is a spiral gear 15 engaging with a spiral gear 16 mounted on a vertical shaft 17, carried in the trunnion bearings of the swivelling column 2. Supported in the spindle tread 5 and mounted to slide on the vertical shaft 17 is a spiral gear 18, engaged with a spiral gear 19 mounted directly on the grinding wheel spindle 6. It will be seen that whilst the axis of the driving pulley 12 maintains a constant position relative to the standard 1, the combination of gears and parts as shown provides for the full required movements and adjustments of the grinding wheel spindle 6. (*Sealed.*)

122,746. The Austin Motor Company, Limited, Northfield, Birmingham, and Sir H. Austin, Northfield, Birmingham. Shafting. (2 *Figs.*) March 27, 1918.—This invention has for its main object means which will readily ensure that one part (such as a flywheel) may be readily put in place in relation to another part (such as a flange around the end or between the ends of a shaft) without need for subsequently inserting bolts through which the drive is transmitted or by



means of which the two parts will be tightly clamped together. A is the flywheel, B the shaft, and C the flange on the end of the shaft. D is one of a number of bolts through which the drive is transmitted from the shaft to the flywheel, and E is one of a number of bolts by which the flywheel is clamped against the outer face of the flange. Each bolt D is a tight fit in a hole of the flange through which it passes, and is prevented from turning in the hole as the nut on the end of the bolt is screwed up; and each bolt E is also a tight fit in a hole of the flange

through which it passes, and is prevented from turning as the nut on the end of the bolt is screwed up. Each bolt-hole for the passage of a bolt D through the web of the flywheel A is formed conical and of a diameter at its smaller end to allow the web to be passed easily over the bolt, and each bolt-hole through the web for the passage of a bolt E therethrough is formed of such diameter as to allow the web to be passed easily over each such bolt also. After the bolts D and E have been pushed tightly into the holes through the flange C, the flywheel is pushed over the bolts and against the flange, and a split conical ferrule F is passed over the end of each bolt D and into the corresponding conical hole, and nuts are run on the ends of the bolts D and E, respectively. In screwing up the nuts of the bolts D, the split ferrules F are forced tightly into the conical holes until they tighten themselves within such holes and also around the bolts D, and ensure that there will be no play or slackness in the drive from the flange C of the shaft B, through the bolts D and ferrules F, to the flywheel. The nuts of the bolts E, when they have been tightly screwed up, preferably against washers, ensure that the bolts E will tightly clamp the flywheel A and flange D together. All the bolts by which the flywheel is fixed to the flange may pass through split ferrules, such as F, which are tightened within conical holes of the web and around the bolt by the screwing up of the nuts, but there would be some liability in such case that the ferrules would be wedged up within the holes and grip so tightly around the bolts as to prevent the bolts being drawn up sufficiently to cause the flywheel and flange to be tightly clamped together, and it is therefore much preferred that in addition to bolts having the ferrules thereabout for the purpose of the drive, there shall be bolts (such as E) for clamping the parts together. *(Sealed.)*

MINING, METALLURGY AND METAL WORKING.

122,672. T. B. Kitson, Leeds. Glass Furnaces. (6 *Figs.*) December 27, 1917.—This invention relates to furnaces. A feature of the invention is that the air for supporting combustion, after passing under the bottom of the furnace from one end to the other, passes up to and along a wide and rather shallow arched chamber, gallery, or flue interposed between the crown of the furnace and an upper flue or exhaust gallery or passage through which the hot products of combustion or waste gases pass to the chimney, such waste gas and air flues being straight and unobstructed; *a* is the body of the furnace, with a low roof or crown *b*. On the left is the working end provided with the projecting discharge outlets *c*. These lead to a wide, shallow waste flue *d* at the top of the furnace, whilst their bottom ends are provided with troughs or spouts having holes for the outflow of the glass. At this working end of the furnace, are also provided short uptakes *e* for the air to support combustion,

Fig. 1.

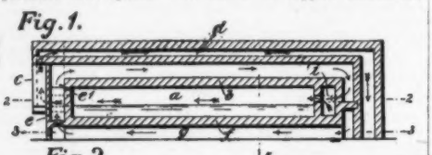


Fig. 2.

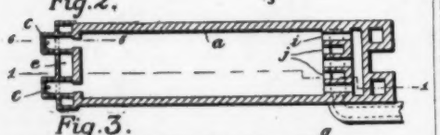
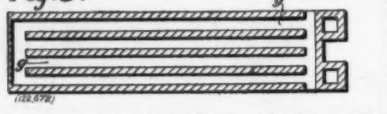


Fig. 3.



which is drawn from beneath the bottom of the furnace. The air enters at the opposite or right-hand end of the furnace and passes through a shallow lower flue beneath the bottom *f* of the furnace. This lower flue is formed of parallel passages *g* between a set of arches which in effect form the furnace bottom *f*. It opens into an arched cross-passage from which the uptakes *e* lead to a cross-passage e^1 built in the working end. The side of this passage in turn opens into the intermediate wide-arched heating gallery or chamber *h* in the top of the furnace. Along this the air passes back towards the inlet end of the furnace, where it enters the latter through ports *i* and at the same time mixes with fuel used for heating, which enters through intermediate parts *j*. The mixture which thus enters the body of the furnace, burns above the molten glass or metal, at the same time passing along the tank or body part of the furnace towards the working end. From this latter the products of combustion finally pass out through the short uptake *c* to the upper flue *d*, whence they flow back to the chimney. *(Sealed.)*

RAILWAYS AND TRAMWAYS.

122,737. C. C. Champeney, Swindon. Train Pipe Couplings. (4 *Figs.*) March 13, 1918.—According to the present invention, the nose-piece, in place of the usual male-threaded portion is formed with a plain face to abut against the face of a branch of an existing end cock and with a coaxial opening through its back wall; a short length of externally-threaded tube formed with a spider or cross-member having a screwed stud projecting from the centre, is adapted to be screwed into the

Fig. 1.

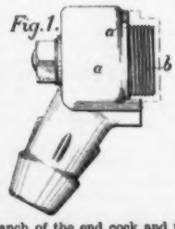
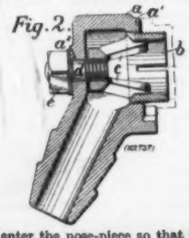


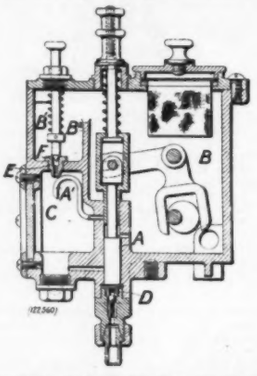
Fig. 2.



branch of the end cock and to enter the nose-piece so that the stud projects through the hole in the back, in which position it is fixed by a nut on the stud. *a* is the body of the nose-piece which is formed with a face a^1 to abut against the face of the cock branch with a co-axial opening a^2 in its back wall. *b* is the threaded tube (shown slotted), *c* its spider, *d* the central stud and *e* the fixing part. The spider of the threaded tube *b* is of projecting conical form, which enables a full area passage-way for steam to be provided without enlarging the cock end. The threaded tube *b* is screwed into the end cock branch (shown in dotted lines) and the nose-piece *a* slipped over the tube *b* as shown, the whole being then tightened up by the nut *e* on the projecting end of the stud *d*. The joint between the end cock and the nose-piece is made with an ordinary grummet, and a rubber washer surrounds the stud. The slotting of the short length of threaded tube *b* is to provide for slight variations in the diameters of threads in existing cocks. *(Sealed.)*

STEAM ENGINES, BOILERS, &c.

122,560. C. C. Wakefield, London. Drip-Feed Lubricators. (1 *Fig.*) April 15, 1918.—This invention relates to drip-feed lubricators. According to this invention, a lubricator of the drip-feed type having two oil-admission orifices, one above the other, one of these being hand-controlled, is characterised by the main body of the reservoir for the lubricant being disposed at the side of the drip-feed chamber, extending over the same, and having a partition (for example, one which extends part way only to the top of the reservoir) to separate the said extension from the main chamber so that the level of the lubricant therein will not drop to the level of the lubricant in the main body of the reservoir as this is lowered by use. The discharge effected by the reciprocating plunger A takes place through the drip-feed nozzle A_1. The reservoir B is normally filled with oil and has an extension B_1 which lies over a sight-feed chamber C in which the drip-feed nozzle A_1 is situated. The drip-feed can be viewed through the glass or other transparent panel and passes out from the drip-feed chamber through a duct whence



it is forced down the delivery pipe D by the bottom end of the plunger A. The extension B_1 of the reservoir B has a partition B_2 which serves to retain oil in it, though the level in the main body of the chamber may have dropped below the level of such oil as is in the extension. In the floor of the extension is a tubular bush E, which lies vertically above the delivery end of the swan-necked drip-feed nozzle A_1. Sliding through the top of the oil reservoir is the rod of a valve F, which valve seats itself on the tubular bush E, and is normally retained there by a spring which surrounds the rod. The top of the rod has an operating handle. With this device it will be seen that the feed normally takes place with regularity through the feed nozzle A_1, which is supplied with a charge of oil at every reciprocation of the plunger A. If, however, it is desired momentarily to increase the supply of oil to the point fed by the drip-feed nozzle, the spring-controlled rod is elevated by hand by means of its handle, so that oil from the extension chamber B_1 flows through the tubular bush E, and its supply is thus added to that which normally discharges through the drip nozzle. *(Sealed.)*

122,561. C. C. Wakefield, London. Force-Feed Lubricators. (2 *Figs.*) April 15, 1918.—This invention relates to force-feed lubricators of the type wherein the pump barrel has a plunger sliding therein, closing one end of the barrel and covering and uncovering an inlet port in the side thereof, a member slidably mounted in the other end of the barrel and forming a fluid-tight joint for the same and covering and uncovering a discharge port in the side of the barrel, and a yielding control for this member which always tends to move it towards the pump plunger; the present invention has for its object

Fig. 1.

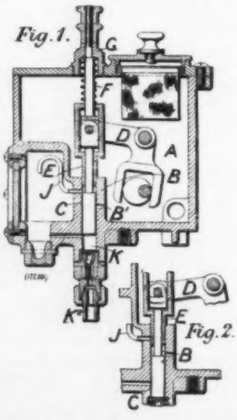
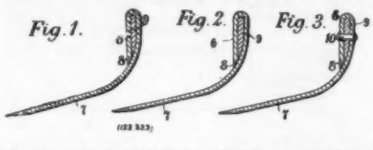


Fig. 2.

to provide means for adjusting the degree of movement permitted the yieldingly-controlled member towards the plunger for the purpose of varying the rate of feed of the pump. According to this invention, a force-feed lubricator of the type described has, in combination with the yieldingly-controlled member, adjustable means for limiting the degree of movement of the said member in the direction of the pump plunger for the purpose of varying the rate of discharge of the pump through the delivery port. The lubricant reservoir A has within it a pump barrel B. In this barrel a plunger C slides, which is connected to a rocking arm D operated by an eccentric. The plunger C closes the lower end of the barrel B, and the upper end is closed by a sleeve E. The sleeve has a stirrup E_1 which extends round the head on the plunger rod, whereby the rod is operatively connected with the rocking lever D and the top of the stirrup engages the headed end of an adjusting rod F. This rod extends through a cap G in the top of the lubricator, and is free to slide therein, being adjusted by a nut. In the barrel B is an inlet orifice B_1, and above this a delivery nozzle J communicates. The delivery nozzle is swan-necked to provide a drip-feed, and is situated in a drip-feed chamber. The lubricant from the chamber flows through a passage into a delivery chamber K, which is situated beneath the plunger C, and above a non-return valve which permits the passage of oil to the delivery conduit K_2. The chamber K is made the same size as the barrel B, so that the plunger C fits it and constitutes a working plunger therefor. In Fig. 2, the plunger C is shown at the limit of its movement downwards and the sleeve E is as far down as it can travel with the adjustment shown in Fig. 1. In this position, oil enters by the port B_1 and fills the space between the top of the plunger C and the sleeve E. The plunger then begins to rise, and in so doing, pushes up the sleeve E by means of the body of oil trapped until this passes the end of the delivery conduit J, when the oil escapes by the delivery conduit and the sleeve travels down to meet the plunger. This is the position of the parts shown in Fig. 1, and the discharge is not completed until the sleeve, under the action of its spring, completes its downward movement. It will thus be seen that by lowering the spindle F, the lowest point to which the sleeve E travels can be varied, and consequently the space between the top of the plunger C and the bottom of the sleeve, when the parts are in the position shown in Fig. 2, will be decreased, and a smaller charge of lubricant will consequently be drawn in at each operation of the pump and discharged through the delivery nozzle. Conversely, by raising the spindle, the charge can be increased, though in the drawings the spindle is shown almost at the limit of its adjustment upwards, as the bottom of the sleeve must always cover the end of the delivery nozzle J when the plunger C is at the bottom of its stroke. The lubricant delivered into the feed-chamber enters the delivery chamber K, as already described, and is forcibly discharged thence by the plunger C as it moves from the position shown in Fig. 1 down to that shown in Fig. 2. *(Sealed.)*

122,323. K. Baumann, Urmston, H. L. Guy, Manchester, J. F. F. Winning, Stretford, Manchester, and The British Westinghouse Electric and Manufacturing Company, Limited, Westminster, London. Fluid-Pressure Turbines. (5 *Figs.*) March 18, 1918.—This invention relates to stationary guide blades employed in the diaphragms of axial flow fluid-pressure turbines of the impulse type. The blades are, according to this invention, made of a single thickness of sheet metal, sheet steel for example, the increase in thickness at their inlet edges necessary to enable them to withstand bending stresses being secured by turning or bending over the sheet metal at these edges, or alternatively by securing a strip of metal to said edges. The bent-over portion 6 at the inlet edge of the blade 7 is preferably not pressed flat against the rest of the blade, as this may tend to damage the metal, but is so turned over as to leave a space between the adjacent surfaces, enabling an easier bend to be employed. The free edge 8 of the bent portion 6 is pressed into close contact with the surface of the blade, and is preferably

Fig. 1. *Fig. 2.* *Fig. 3.*

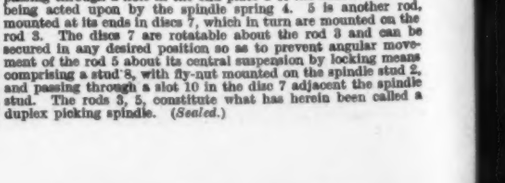


chamfered or reduced in thickness so that the inner surface of the finished blade will present a substantially continuous curve. If desired the free edge 8 may be welded to the main portion of the blade as shown in Fig. 2. The bent-over portion 6 of the blade is either closed at the ends of the blades by welding, or the space within the bent-over portion is filled either completely or at the ends only of the blade with a strip or strips of metal 9. This is desirable, as otherwise when the blades are secured to the diaphragm by casting, the hollow spaces left within the turned-over portions of the blade might be partly filled with cast metal, particles of which might become detached and cause serious damage to the turbine. It has also been found that blowholes are liable to be formed near the embedded ends of the blades when the diaphragm is cast around them, unless the ends of the blades are either closed by welding or filled up as described. In the construction illustrated in Fig. 3 the free edge 8 of the bent-over portion of the blade, as well as the filling-piece 9, is held in position by means of rivets 10. *(Sealed.)*

TEXTILE MACHINERY.

122,662. A. Newton-Smith, Westminster, London. Picking Mechanism for Looms. (5 *Figs.*) November 26, 1917.—This invention relates to the picking mechanism of looms. According to this invention, the picker is mounted on, and traversable along, a pair of rods arranged parallel the one with the other, herein called a "duplex" picking spindle, and one or both of which rods is, or are, carried at its, or their, ends by means that are carried by the spindle stud and the end plate of the shuttle-box, and are rotatably adjustable in relation thereto. 1 is the end plate of the shuttle-box and 2 is the spindle stud. 3 is a rod, which, in the ordinary arrangement, would form the

Fig. 1. *Fig. 2*



picking spindle. The rod 3 is mounted in the same manner as is a picking spindle, that is to say, one end is contained in, and carried by, the spindle hole in the spindle stud 2, the other end passing through a hole in the end plate 1 of the shuttle-box and being acted upon by the spindle spring 4. 5 is another rod, mounted at its ends in discs 7, which in turn are mounted on the rod 3. The discs 7 are rotatable about the rod 3 and can be secured in any desired position so as to prevent angular movement of the rod 5 about its central suspension by locking means comprising a stud 8, with fly-nut mounted on the spindle stud 2, and passing through a slot 10 in the disc 7 adjacent the spindle stud. The rods 3, 5, constitute what has herein been called a duplex picking spindle. *(Sealed.)*